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THE STUDY OF ASTRONOMY.

WM. W. PAYNE.

The study of astronomy, in a broad and general sense, may be considered in three different ways. The first, as regards a preparation belonging to liberal and general scholarship; secondly that now needed to fit a person well for positions of instruction in the high school, academy or college, and, lastly, such a course of study and practical training as is adapted to the wants of those who plan to follow a professional career.

The study of astronomy is advancing with wonderful rapidity, and popular knowledge in every part of its wide field of research is now easily gained, so that common acquirements in this science mean more than they did ten years ago. Why this is so is readily understood by the casual observer; and it is true because the public schools are doing far better work in science than they knew how to do even five years ago, the daily press has extended its range of schclarly observation, and is now taking notice constantly of all important phases of scientific development and scattering the information, as news, broadcast everywhere, with wonderful celerity. In this regard the daily newspaper has become a potent factor in promoting intelligent and progressive study, and a powerful stimulant to healthful activity in public thought in all useful science. As a consequence of better public schools and a more efficient daily press, magazine literature and popular books on scientific subjects have an increasingly high standard and are broadened in scope, without necessarily involving technical expression, or much of the terse and severe language of the higher mathematics, until, now, these channels of the more formal and exact thought have become so numerous and comparatively so cheap, as to be easily within the reach of thousands of people who, a few years ago, had neither the inclination nor the means to purchase them, nor even the ability to read them very intelligently. It must be evident to the thoughtful person, that we must take account of these new conditions of intellectual life about us in any attempt that may be made to offer pertinent and helpful suggestions.

By liberal and general scholarship we do not mean necessarily the cultivation of mind gained in a full course of study at some reputable college, as desirable and valuable as that may be. But we do mean, such a knowledge of the principal branches of science as will enable any person easily and usefully to keep in touch with the great and vivid life that is going on around him every day. To do this it is necessary to gain a knowledge of men and things and books by observation and methodical study. These common avenues of information are open to all, and if used as they may be by industrious students, they will be a source of rapidly increasing mental power. But the usual obstacle in the way of all this is the fact that the inexperienced person does not know how to go at the work to make a right start, nor does he know how to continue it methodically, so that the study itself shall furnish all needed stimulus in self-guiding effort in such a pursuit, which is the lot of many who might do well under such circumstances with a little help at the right time and place.

Now it is the purpose of this article and others to follow to offer some suggestions of ways and means to cover these points in relation to the study of astronomy. In other words how, or where, shall a beginning be made? On this point it is suggested that our student, or general reader, start with a standard text book on the elements of astronomy, to bring to mind the leading facts of the science and to give him right ways of thinking and proper expression for these facts when he wishes to use them. For this foundation work, in our judgment nothing can take the place of a well-written, modern text-book. The book should be of undoubted authority, and in its treatment of the elements of astronomy it should give a fairly general view of all the different things that scholarly astronomers now recognize as essential parts of the science as a whole. "The Elements of Astronomy" by Professor C. A. Young more nearly represents the idea we now have in mind than any other of the kind with which we are acquainted. Such a book as this should be read and re-read thoroughly and exhaustively, and it should not be laid aside, more than temporarily, until the object for which it was chosen is certainly realized. In a first reading the divisions of the subject, their relations to one another and the more important facts belonging to each will naturally claim almost exclusive attention. The earnest reader will soon see that the task of his first reading easily falls into six important divisions with the following titles: Moon, Sun, Planets, Comets, Stars and Nebulæ. The general relations of these celestial bodies in the heavens will be readily and

definitely comprehended, and some idea of their respective motions and their influences on one another, in time and space, will be gained, and will excite thoughtful wonder in the mind of the careful reader, for such astonishing facts are likely to arouse the imagination and to leave very strong and lasting impressions if they are rightly understood.

But the object sought in this text-book work will not be gained usually by a single reading, because the matter is too full, compact and varied for sufficient mastery by one such effort. A second reading at least will be very desirable, if not really necessary for the working knowledge of the subject aimed at in the plan before us. The object of this is plain, and has already been intimated in what has been previously said. The reader will need to fix clearly and firmly in mind the concept of the celestial sphere with its frame-work of points, lines and circles so as to realize distinctly, in mental picture, the places and movements of these bodies while any facts relating to them are under consideration. The idea of an oblique sphere and the observer's place on the Earth which makes such a sky picture possible are essential things, and they should be fully mastered early in this second reading, if not before. The importance of this can not be overestimated, and a lack of its clear comprehension will cause confusion of ideas later. A small globe will be a help at this point, for it will easily show the positions of the right and the parallel spheres which are easy steps in the explanation of the oblique sphere. The common names and the uses of these points, lines and circles then follow and the sky picture is quite complete, and it should be realized as the skeleton of this immense Universe surrounding us, and not simply and only as a picture of something in a small book.

It may be remarked in this connection that here is opened a fruitful field for the exercise and culture of the imagination, that important faculty of the mind of which so much has been said by scholars in modern times in treating it as a powerful instrument in scientific investigation. The resources of astronomy for this purpose are evidently exhaustless.

If the work is well done so far, our reader may now undertake a second reading of the first topic in our series, viz:—The Moon. This theme is placed first because ordinary readers generally know more about the Moon than they do about other celestial bodies, because it is our nearest neighbor, and because, in most particulars, the topic is easier than others of the six previously named.

From the previous reading it will not be difficult to draw up for our note book the outline of a topical scheme relating to the Moon, so that all further reading shall bear directly and pointedly on the object before us. In this way a person will remember what he reads, because he relates it properly with other knowledge on the same topic, and so enables the mind easily to hold the larger body of well ordered truth in place by the law of association. It will be an advantage to the reader if he faithfully follows this suggestion. He will not then complain, after a little, that his head is like a sieve unable to retain much of anything that goes into it.

For this outline we suggest something like the following, as a model to be worked out in the reader's own individual way. The numbers should be placed far enough apart so as to give space for concise and neatly written notes under each as the reading progresses, and care should be given to this work for it may prove very valuable later in many ways as the information it contains shall be wanted.

THE MOON.

1. Distance from the Earth. Size in miles.
2. Orbit of the Moon as related to the Earth, its size and shape.
3. Motions, revolution and rotation with the velocities of each.
4. Mass, density and force of gravity at the surface.
5. Phases, their causes.
6. Light and heat.
7. Eclipses, their relation to chronology.
8. Telescopic appearance.
9. Physical condition of the surface.
10. Lunar influence in meteorology.
11. Photographs and maps of the Moon.
12. Astronomical study of the Moon now going on.

The first three numbers of this scheme present facts that are now generally well determined, and the most of them may be committed to memory as the knowledge of them is of common use. The other points are themselves so interesting that the knowledge of them will be eagerly pursued for its own sake and further suggestions seem unnecessary.

After this topic is completed by the use of the text book, if additional reading is desired, such books as Nasmyth and Carpenter and Neison on the Moon will be found among the best.

We will next time offer suggestions to accompany the reading of the second topic, the Sun.

A CHART OF CIRCUMPOLAR STARS.*

H. C. RUSSELL, B. A., C. M. G., F. R. S.

Circumstances have frequently brought under my notice the difficulties felt by amateurs in finding, on the ordinary star charts, the several stars which they may see in the heavens, and hence I have designed a chart of southern circumpolar stars, which I thought would be more convenient and easy for them to use than the star charts previously published. I have also introduced some results from my own work which seemed desirable additions to the information usually given; these will be referred to later.

For the ordinary amateur's use, too much has been attempted on the best star charts. He wants to recognize the visible stars in their relative positions, and not to have the chart crowded by details which only come to him in later studies. The smallest star put in is 6.5 magnitude, and should be visible to good eyes on a fine night. It is possible that some stars are visible which are not in the catalogues and which will therefore not be found here. Great care was taken in selecting sizes for the star spots which would make it easy for the eye to pick up the bright stars, and in order still further to aid in this ease in using the chart, each star to the fifth magnitude inclusive has projecting rectangular bars, the number of which at once decides the magnitude, and all stars of 5.5 to 6.5 magnitude are simply round spots. The abbreviations used are all shown on the chart for easy reference, and on the outer rim a series of dates by which to set the chart. If any date is set vertically over the centre of the chart, then at 8 P. M. of that date, the stars bear the same relation to the horizon and the points of the compass (when looking south), as they do when one looks at the stars themselves.

All the star clusters which one could see under favorable circumstances with a three inch telescope have been put in,—for the selection of these our own photographs were very useful—all are distinctly marked by the letter C in a circle. It is hoped that the ease with which these may be found will be a convenience to many. The star positions have been computed and plotted for the epoch 1900, so that the chart will be available for some years without serious errors from precession.

The intention is to have the chart printed on thin or translucent paper, which may be placed on a circular piece of glass or other

* A paper read before the Royal Society of N. S. Wales. See frontispiece

translucent material, so that it can readily be turned round in a holder in accordance with the instructions on its margin, when it is desired to get the stars on it into the positions then occupied by the stars in the heavens. This method of mounting is not new, but has been too much neglected, and I have adopted it because I think it will be a most important aid to the beginner, who as a rule gets very much confused by having to look at a star chart bound up in a book and placed the wrong way, and then mentally turn it round into the position in which he sees the stars in the heavens. In use it will be found exceedingly convenient to have some sort of frame or box which the star chart can be placed upon close to a lamp, and if much use is to be made of it there is a decided advantage in having a box which will hold the lamp and the chart in the most convenient position. It is an advantage to have the chart neither vertical nor horizontal, but in a position midway between these two, so that when one is in the ordinary position for reading, the chart is at right angles to the line of sight, and therefore in the most convenient position to use. Provision should also be made for turning the star chart round and setting it in any desired position.

The original drawing measures thirty inches in diameter, and the greatest care has been taken in plotting the stars in their exact positions, and in making every detail as clear and sharply defined as possible, and the lettering is on such a scale that everything can be read, even when the chart is photographically reduced to a diameter of six inches, and if a magnifier is used, the chart may be reduced to three inches diameter and retain every detail sharply defined.

The computations for the positions of the stars have been carefully made and verified, and then compared with those on existing star charts, and when any difference was found, great care was exercised to ascertain the correct position, and it is satisfactory to be able to state that this process resulted in finding confirmation of our positions.

In some cases the star magnitudes are uncertain, because the best authorities differ; in these cases the magnitudes given in the Argentine General Catalogue have been taken.

The form of the Magellan Clouds have been put in from actual photographs taken to the scale of the map, and only the brighter parts are shown—the parts most interesting to the possessors of small telescopes—they look very different from what is put to represent them in other star charts of this region, but these are certainly the forms of the brighter parts. Some slight changes

appear in the Milky Way. To my eyes and those of the assistants in the Observatory, the great rift said to begin at Alpha Centauri really extends and includes Beta Ceutauri, only it is not so dark between these stars. Again the Milky Way clearly encloses the northern part of Crucis. I have followed the usual course in showing the Coal Sack dark, also in regard to the great rift in Argo, although my photographic examination of these regions shows them to be full of stars.

It would seem to many that there was no need to add to the number of charts of southern circumpolar stars. Nothing, for instance, could be better than the one published by the late Mr. Proctor, for the classes he meant it for—students and observers, i. e., those who know something about the stars or have teachers —there is a wider circle who know less, and these I have endeavoured to reach.

CHRONOLOGICAL NOTES—II.

R. W. McFARLAND.

For Popular Astronomy.

The Calendar.—In the preceding article the general facts concerning the Calendar were given; but the subject was not exhaustively treated. Besides the changes made by Augustus and which have already been given, another was introduced at an early date, but the exact time, I think, has never been ascertained. Nor do I know certainly by whom the change was made although it is most likely that this, too, was made by Augustus. I refer to the insertion of the extra day of leap year, into the body of February, so to speak. The old Roman year consisted of twelve lunar months—355 days—as before explained. The method of adjusting this period to the solar year, was by inserting a short month of 22 days immediately after the 23d of February in one year, then at the end of the next two years, a month of 23 days, and so on alternately.

The 23d of February was the festival of Terminus, the god of boundaries. Numa is credited with the establishment of this festival, which was usually called the Terminalia. The god himself was supposed to take care that boundaries should not be disturbed. From the solicitude manifested on the subject, one would naturally suppose that there had been frequent infractions of rights in this regard. One verse in the 27th chapter of Deuteronomy reads as follows: "Cursed be he that removeth his neighbor's land-mark. And all the people shall say Amen." In

Ohio this offense is a misdemeanor, punishable by imprisonment in the penitentiary—after the culprit is caught.

The calendar of Cæsar wholly changed the old method of intercalation after February 23d. But innovations are usually unwelcome to the multitude. The distribution of the days of the year into 12 months, having 31 and 30 days alternately, was an innovation of very large proportions;—one likely to excite opposition. In 1752 there were riots in England, when, in changing from *old* to *new style*, eleven days were dropped. If the Roman multitude could clamor for "bread and circuses," equally it might clamor for the lost days after February 23d,—lost, according to the ancient and customary way.

The Terminalia was the last of the old Roman yearly festivals; and, as above explained, had been followed by a sort of holiday period. (It will be borne in mind that the year ended with February). It seems to me probable that the "multitude" demanded a return to the old way, and were gratified by the insertion of the extra day of leap year, in the accustomed place: viz., immediately after the 23d. I know it has been said that this was done by Cæsar himself. Of this there is not sufficient documentary evidence; besides, it would have been in direct violation of the general plan of reformation, and he himself survived the reformation only a few months. Furthermore, the word *bissextilis* which, from the time of its invention, has always stood for the 24th of February, could not have been so used until February contained only 28 days, and that was not the case until the time of the changes made by Augustus, nearly 40 years after the death of Julius Cæsar.

Supposing then that this extra day was inserted immediately after the 23d, in accordance with the old way, it would be what we call the 24th, but by the Roman method of counting it was "the 6th day before the Calends of March." The succeeding day would be the *regular* 24th, and in the Roman count, would be the "second 6th day before the Calends," *i. e.*, in Latin, "ante diem *bissextilem* Calendas Martii." Those who say that the extra day was inserted between the 24th and 25th seem to me to be in error. In the absence of contemporary historical proof, the above appears to me to be the natural and sufficient explanation.

So far as I have been able to ascertain, this extra day was not reckoned afterwards as the 29th, until the times of the disruption of the church 400 years ago. The writer of the article "Calendar" in the Encyclopedia Britannica says that in the ecclesiastical Calendar this *second* 24th is still used.

The Week.—This is a period unknown to the Greeks and Romans in their palmy days. I pass over the subdivision of the month as practiced by these nations. The invention of the week is attributed to the ancient Egyptians, long before the time of Moses. It has no connection with any natural division of time, except as a multiple of a day. Why the ancients selected the number seven, is only a matter of conjecture. Most probably it was chosen because there were seven planets—so-called—in those far-off times.

In estimating the relative distances of the planets, it was taken for granted that the slower the motion, the more distant was the planet. In this way the seven planets fall in the following order: Saturn, Jupiter, Mars, Sun, Venus, Mercury, Moon. Now these planets, or the deities having the same name, give the several names to the days of the week: and taking the days in the same order as the planets, we have Saturday, Thursday, Tuesday, Sunday, Friday, Wednesday, Monday. But this is not the order of the days. How came the change of the order? To this question I have seen but one answer. It seems far-fetched and, on its face, improbable, but yet it fits in exactly with the facts. It is this: It is asserted that the hours of the day were, by these old Egyptians, consecrated to these seven deities, in regular order.—It may be well to bear in mind that the 24 hours of the day is also credited to the same ancient people, as well as the sexagesimal division of the hour and minute, and of the degree,—Write the names of the deities in order, and set their respective days beside them, thus:

Saturn	1	Saturday.
Jupiter	6	Thursday.
Mars	4	Tuesday.
Sun	2	Sunday.
Venus	7	Friday.
Mercury	5	Wednesday.
Moon	3	Monday.

According to Dio Cassius, the Egyptian week began with Saturday. With the Jews in later times and among modern nations, it ends with Saturday. Let the first hour of Saturday be given to Saturn; the second, to Jupiter; the third, to Mars, and so on, repeating the list over and over, Saturn will have the 1st, 8th, 15th, and 22d hours, Jupiter will have the 23d, and Mars the 24th, which ends the day. Then proceeding in order, the 1st hour of the second day will fall to the Sun, as do, also, the 8th, 15th, and 22d. The 23d falls to Venus; the 24th to Mercury. So the second day ends.

The 3d day then begins with the Moon. In like manner continue through the 7 days. The first hour of the successive days will fall to the deities numbered 1, 2, 3, etc.; then taking the days of the week in the order of the numbers, 1, 2, 3, etc., we have the order, Saturday, Sunday, Monday, etc.

It may be of interest to some, to compare the names of the days of the week, as used now and heretofore. The English names are derived from the Anglo-Saxon, but I give them an English dress. I take five sets.

Latin.	Anglo-Saxon.	English.	German.	French.
Dies Solis	Sun's day	Sunday	Sonntag	Dimanche
Dies Lunæ	Moon's day	Monday	Montag	Lundi
Dies Martii	Tiw's day	Tuesday	Dienstag	Mardi
Dies Mercurii	Woden's	Wednesday	Mittwoch	Mercredi
Dies Jovis	Thor's day	Thursday	Donnerstag	Jeudi
Dies Veneris	Friga's day	Friday	Freitag	Vendredi
Dies Saturni	Seterne's day	Saturday	Samstag	Samsdi

The nations denoted by the three inner columns are very closely related in origin and history; and the days of the week have, substantially, the same names. The Latins had far more influence in France than they had beyond the Rhine; and the similarity of the Latin and the French names, is easily seen, except in the word for Sunday. In the second chapter of Tacitus's account of the Manners and Customs of the Germans, he says, "Celebrant carminibus antiquis, Tuisconem deum, terra editum, et filium Mannum, originem gentis conditoresque." [They celebrate in ancient songs, that the god Tuisco who sprang from the Earth, and his son Mannus, were the origin and founders of their nation.] It is seen that our orthography of *Tuesday* corresponds very closely with the Latin spelling of the name of the old German deity, who, in Anglo-Saxon, was called Tiw.

At what hour does the day begin? Some nations, as the ancient Chaldeans, began the day at sunrise; others, as the Jews, at sunset. In the 5th verse of the 1st chapter of Genesis we have, "And the evening and the morning were the first day." This method is in universal use with that people even to this day, so far as I know. The ancient Egyptians as well as most modern nations made or make it midnight. Ptolemy the Alexandrian astronomer, about A. D. 150, began the day at noon; and his brother observers to this day follow his lead; and for an obvious and valid reason.

Such are a few of the points philological, astronomical, and historical, which can be made, if one is curious to look into such things. And usually the more one studies these things, the more interesting they become to him.

THE GRAPHIC CONSTRUCTION OF ECLIPSES AND OCCULTATIONS.

WM. F. RIGGE, S. J.

VI.—Eclipse Maps.

For Popular Astronomy.

The Ephemeris gives each year charts of the solar eclipses visible on the Earth, with the path of the total or annular eclipse, or the point of the maximum eclipse when it is only partial, together with the northern and southern limits, and the lines of beginning and ending for every hour of Greenwich Time. Any one interested in these eclipse charts must have often wondered at the peculiar shapes many of the lines assume, and must have ardently wished to divine the secret of their origin. Thus, in the annular eclipse of July 29, 1897 (see next year's Ephemeris or Fig. I of this article), we notice a central line, the path of the annular eclipse, with northern and southern limits approximately parallel to this central line, and at the eastern and western ends peculiar egg-shaped ovals, the western one of which, however, is only partially drawn on Fig. I. In the total eclipse of Sept. 28, 1894 (see Ephemeris for that year or Popular Astronomy for that month on page 40) the southern limit disappears; and in the annular eclipse of April 5, 1894 (Popular Astronomy for that month on page 330), and in the total eclipse of August 8, 1896 (Popular Astronomy of last January on page 237) the northern limit disappears; and in the partial eclipse of Sept. 18, 1895 (see Ephemeris) there is not even a central line, but only a point marked "Greatest Eclipse"; while the ovals in all three eclipses have lengthened so much as to unite and run into one another, their relative sizes being often quite disproportionate. What is the reason of this difference? How are the lines, especially the ovals, obtained? Do I need to know much more about mathematics in order to follow the explanation? Could I understand it at all?

To these questions we reply that no more mathematics is necessary for this article than for any preceding one, so that if the reader has passed the entrance examination mentioned in the beginning of this series of articles (in the preceding December number on page 184) he need have no fear of being led into abstruse or unintelligible matters which are far above his comprehension, for we shall remain strictly within the bounds there laid

down. But if we shall not require more knowledge from the reader, we must instead require more time and a great endurance. And we can promise him in return that even if he will never have the leisure or the inclination necessary to construct an eclipse chart, the knowledge of how it is done will more than repay the time spent in its study.

In order, then, to give some idea of how eclipse charts may be constructed graphically, we shall as heretofore take a practical example, and as such we select the eclipse of July 29, 1897, with which we have already become familiar in the second article of this series (POPULAR ASTRONOMY for January and February of this year). In the construction of exhaustive charts of this eclipse for the entire United States, we shall give plentiful directions, and state also the accuracy to which the graphic process may lay claim, and afterwards generalize the whole method by adding what may be different in other eclipses. And lastly we shall say a few words on a method which is partly graphic and partly numerical, and with it bring this series of articles to a close.

The Principle of the Method.—In order to introduce the reader at once into the principle of the method which we are going to use, we would call his attention to Fig. I, which represents the Earth as seen from the Sun at $8^h\ 26^m$ A. M., Central Time, on July 29, 1897, with the Moon's penumbra centered on the Gulf of Mexico. We have chosen this moment because then the obscuration is a maximum for the central portion of the United States. The preceding or right-hand half of the penumbral circle on our diagram passes through all those places at which the eclipse is beginning at this same instant of absolute time, that is, at 8:26 A. M., Central Time. The reader may trace this circle from the middle of British North America, through the Gulf of St. Lawrence, the Atlantic Ocean, and through the northwestern portion of South America. The outlines of these countries and seas have been filled in from a geography, after the meridians and parallels of latitude had been drawn according to the method to be explained presently, the longitude of the central meridian at the given instant being 35° west of Greenwich. The following or left-hand half of the penumbral circle has not yet fully entered upon the Earth's disk. It would pass through all those places at which the eclipse is ending at the same given instant, 8:26 A. M., Central Time. The concentric circles within the penumbra show the obscuration expressed in tenths at this same instant for the points through which each of them passes. The long straight

line crossing the Earth's disk is the path as seen from the Sun of the centre of the Moon and penumbra across the sunlit disk of the Earth, or what would be the path across the Earth if the Earth did not revolve on its axis but continued to present the same face to the Sun. Its construction, as well all as other data relating to this figure, will readily be understood by reference either to our second article (January of this year) or to a later part of the present one.

If the Earth did not rotate on its axis, it would be quite an easy matter to construct an eclipse chart, for all we would be obliged to do would be to centre a transparent disk representing the penumbra on as many points as we like of the path of its centre across the Earth, say at every hourly or half-hourly or ten-minute position, and then trace the course of its edge across the countries and seas on the map in the same way as we may follow the penumbral circle on Fig. I. But the rotation of the Earth, if it takes away this beautiful simplicity, does not, however, complicate matters to any great extent, because it changes only one factor in the problem, and that is the longitudes. This is very well illustrated on Fig. I. The Earth's disk with its continents and seas, as also the Moon's penumbra, will, as we may be allowed to repeat, occupy the exact positions on the map when viewed from the Sun at $8^h\ 26^m$ A. M., Central Time, on July 29, 1897. About an hour and a half later, that is, at 10 o'clock, the penumbra's centre will be at X on its path. If the Earth did not rotate, the place on which the centre of the penumbra would fall would be in longitude 35° west of Greenwich and in latitude 14½° north. But during this hour and a half the Earth turns through 23° with regard to the Sun ($10^h\ 0^m - 8^h\ 26^m = 1^h\ 34^m = 23°.5$), hence its rotation brings the place just mentioned 23° farther to the east, while a second place 23° west of this one is carried in its stead directly into the centre of the penumbra, that is, the eclipse will be central at 10 A. M. at the place whose longitude is $35° + 23° = 58°$, but whose latitude is the same, 14½° north. Similarly, the point where the eclipse is central at XI^h, will be shifted 15° more in longitude than the one at X^h, while its latitude will be unaffected. In this manner the straight line VIII — XII becomes the curved line which is entitled "Path of Annular Eclipse."

The reader may now probably see the solution of the problem. We draw the Earth's disk with its meridians and parallels of latitude, but we need not outline the continents and seas, because the positions we could give them would be true only for a mo-

ment. Such a drawing is given in Fig. II, which differs from Fig. I mainly in this, that Fig. I gives a view of the Earth's actual sunlit hemisphere with its continents and seas as it will appear when looked at from the Sun only at a certain given instant of time, while Fig. II represents the fixed mathematical sunlit hemi-

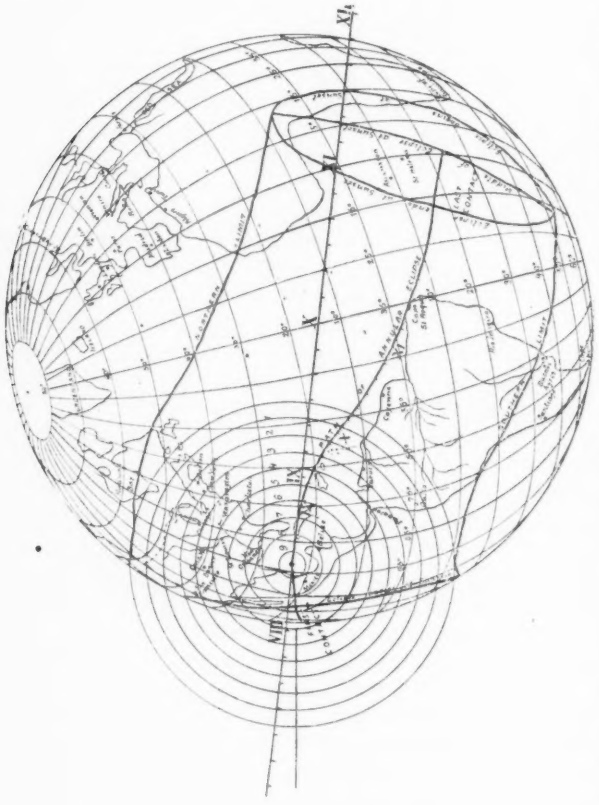


FIG. I.—THE EARTH AS SEEN FROM THE SUN AT 8h 26m A. M. CENTRAL TIME, JULY 29, 1897.

sphere for the whole day of the eclipse, with fixed meridians and parallels enclosing the terrestrial globe like a wire cage, under or within which the globe revolves. Both figures are the same in construction and both are orthographic projections of the terrestrial sphere upon the fundamental plane. In Fig. II the north pole is put at the top of the map, while in Fig. I the central meridian, and consequently the whole diagram, has been turned on

the paper through the angle $\theta = 14\frac{1}{2}°$ in order to make the plane of the ecliptic horizontal, as is customary in figures which represent the Earth moving through space in its orbit around the Sun. (The angle θ just mentioned is found from the equation

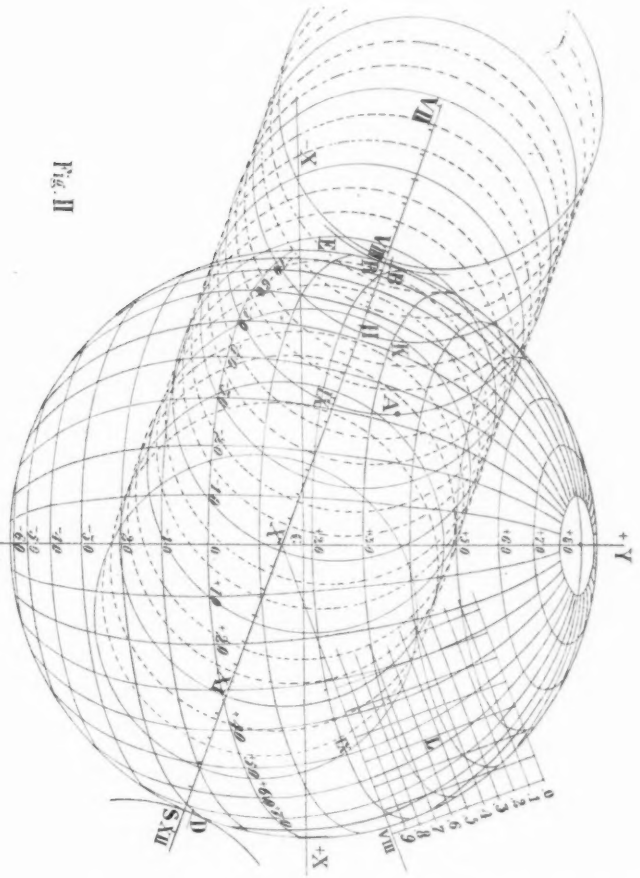


Fig. II

Earth's Sunlit Hemisphere for Whole Day of the Eclipse.

$\cos\theta = \cos\omega \sec\delta$, in which $\omega = 23° 27'$, the inclination of the ecliptic to the celestial equator, and $\delta = +18° 36'$, the Sun's declination.) Both figures, that is, Figs. I and II, are but the completion of Fig. I in our second article (pp. 250 and 310), in as much as they give the diurnal orbit not of one place only but of all places on the Earth.

After drawing the Earth's disk as in Fig. II with its meridians and parallels, we lay down the path of the penumbra and subdivide it as we like to hours or half hours or ten minutes after the manner of our second article (p. 253). Then we draw the penumbral circle for any given moment, say a full hour of Greenwich or Central Time. In Fig. II the penumbral circle is drawn for every ten minutes from $7^h\ 0^m$ to $10^h\ 30^m$ Central Time, the hourly positions being drawn in heavy lines, the half-hourly in lighter, and the rest in dotted lines. We select as many points on the circumference of the penumbral circle in a given position, such as for example at $8^h\ 0^m$, as experience will show us to be necessary. We take the latitude, φ, of each of these points by inspection from our diagram. Thus, for instance, for the point A on the penumbral circle for $8^h\ 0^m$ the latitude, φ, is $+ 35°$. In estimating these latitudes we make use of the parallels of latitude and imagine that we are looking upon a globe, for our diagram is really the projection of a globe. We in like manner estimate the hour-angle, τ, or difference of longitude of the same point from the central meridian. Thus, for A, $\tau = - 33°$. Then if we know the longitude of this central meridian at that moment, the longitude, λ, of our point becomes known. This longitude of the central meridian is called μ by the Ephemeris and is to be found on page 415, where the value of μ for $8^h\ 0^m$ Central Time, that is, $2^h\ 0^m$ Greenwich Time, is seen to be $28\frac{1}{2}°$. Hence, knowing in this manner the latitudes and longitudes of a number of points at which the eclipse begins or ends at a certain moment, we can locate these points properly on a map of that part of the world, and connect them by a smooth curve in order to embrace all intermediate points.

This is the manner is which eclipse charts are constructed, and as we may see already, there is question much more of a certain degree of patience and endurance than of great knowledge. Although the labor of constructing an eclipse map may be great when compared with the construction of an eclipse for a particular place only, still when compared with numerical methods, the graphic method is more expeditious than any, and as far as the construction of ordinary eclipse charts is concerned, equally as accurate. And as we are interested more in the principles than in the actual construction of such eclipse maps, the graphic method will serve to illustrate the process very well for those of our readers to whom more technical treatises on the subject are sealed volumes. But to those who are fond of geometrical drawing on an astronomical subject, we could hardly recommend a more in-

teresting field. We shall therefore give plentiful directions, and hint at a great variety of interesting points which the reader may study and develop at his pleasure with the satisfaction that the solution is his own and that he has learned something by the process.

The Earth's Disk, with its Meridians and Parallels of Latitude.— We begin the construction, therefore, by drawing the meridians and parallels of latitude of the Earth for every ten degrees. (See Fig. II.)

As these meridians and parallels are projected upon the drawing as ellipses, it is well to procure or make an ellipsograph. (See Fig. III.) Such an instrument may be built in this manner: We take two brass squares, such as may be broken from the brass frame of an old clock. We make sure that they have smooth and straight edges and that the right angles are true, and then fasten them together so as to leave a narrow slot between them. We

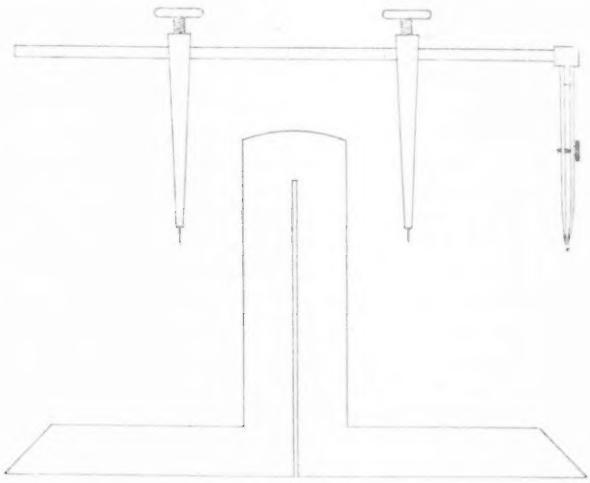


FIG. III.

next take a piece of square rod (umbrella wire will do) about six inches long, and fasten a drawing pen at right angles to one end. Two sliding legs with rounded pin-or needle points and thumb screws, will complete the outfit. The legs and drawing pen must be of exactly the same length, and their ends must always be in a straight line. To use this ellipsograph, we set the sliding legs so that their distances from the pen are equal to the semi-axes, *a* and

b, of the ellipse. Then placing the brass double-square or half-trammel with its longer and free side on the major axis and the slot on the minor axis, we slide the central leg along the major axis while the other leg follows in the slot of the minor axis. In this way half the ellipse is drawn. The apparatus must be reversed for the other half.

The values of the semi-axes of the parallels of latitude and the distance of their centres are computed according to the usual formulæ, $a = \cos \varphi$, $b = \cos \varphi \sin \delta$, $d = \sin \varphi \cos \delta$, taking φ for every ten degrees, the radius of the Earth's disk being, of course, unity. For this eclipse, $\delta = + 18^\circ 36'$. This will give nine ellipses to be computed, the northern and southern being equal, and fifteen to be drawn. If we have the ellipsograph just described, the major axes need not be drawn, but the centres of the ellipses (the values of d) should be marked, and for each of them the double square should be so placed that its free edge passes through the point, and the middle of the slot coincides with the central meridian.

The meridians are drawn more quickly, because they all have the same centre, C, and the same semi-major axis, A, equal to the radius of the disk, unity. Their minor axes, $B = \sin \tau \cos \delta$, are however unequal, and their major axes are not parallel to one another and to the axis of X, as the major axes of the parallels of latitude are, but they are all inclined at different angles, the angle α, which each major axis makes with the axis of Y being obtained from the formula $\tan \alpha = \tan \tau \sin \delta$, τ being taken for every ten degrees. This will also give nine ellipses to be computed, as the eastern and western are equal, and seventeen to be drawn. The value of τ need not be taken greater than 90°, because each meridian, and consequently its projection also, after passing through the pole changes its longitude and its hour angle by $\pm 180^\circ$. Thus, for example, the first meridian ellipse on the right side, where $\tau = + 10^\circ$, will on the other side of the pole be the ellipse of $+ 10^\circ \pm 180^\circ = + 190^\circ$ or $- 170^\circ$; the $+ 80^\circ$ ellipse will pass the pole as the ellipse of $+ 80^\circ \pm 180^\circ = + 260^\circ$ or $- 100^\circ$; the ellipse for $+ 90^\circ$ is the same as the one for $- 90^\circ$; and so on.

The computation of these two sets of ellipses will be expedited by writing the values of log sin and log tan (log cos is hardly necessary) for every ten degrees in two parallel columns, and log sin δ and log cos δ on the edge of a slip of paper, and then holding the latter to the other logarithms according to the method we saw in the second article (p. 252).

The following are the data for all the ellipses when $\delta = + 18^\circ 36'$. A being everywhere equal to 1.000 is not given.

Parallels of Latitude.				Meridians.		
φ	a	b	d	τ	B	α
0°	1.000	0.319	0.000	0°	0.000	0° 0′
10	0.985	.314	.165	10	.165	3 13
20	.940	.300	.324	20	.324	6 37
30	.866	.276	.474	30	.474	10 26
40	.766	.244	.609	40	.609	14 59
50	.643	.205	.726	50	.726	20 49
60	.500	.160	.821	60	.821	28 55
70	.342	.109	.891	70	.891	41 14
80	.174	.055	.934	80	.934	61 4
90	0.000	0.000	0.948	90	0.948	90 0

In case the reader should prefer to know the position of the foci of the ellipses, they may be found very easily. The distance of either focus of a meridian ellipse from its centre is $C = \cos \beta$, β being found from B which is equal to $\sin \beta$. In the case of the other ellipses, the projections of the parallels of latitude, the focal distance from the centre is $c = \cos \varphi \cos \delta$. If the foci of all the meridian ellipses are plotted, they will be found to lie on the circumference of another ellipse equal in all respects to the equatorial ellipse, but at right angles to it, and the foci of this latter ellipse are the projected north and south poles of the Earth. The foci of the projected parallels of latitude will, if plotted, be found to lie on the circumference of a circle concentric with the Earth's disk with its radius equal to $\cos \delta$. The demonstration of these facts is not very difficult. We must, however, leave it to the reader.

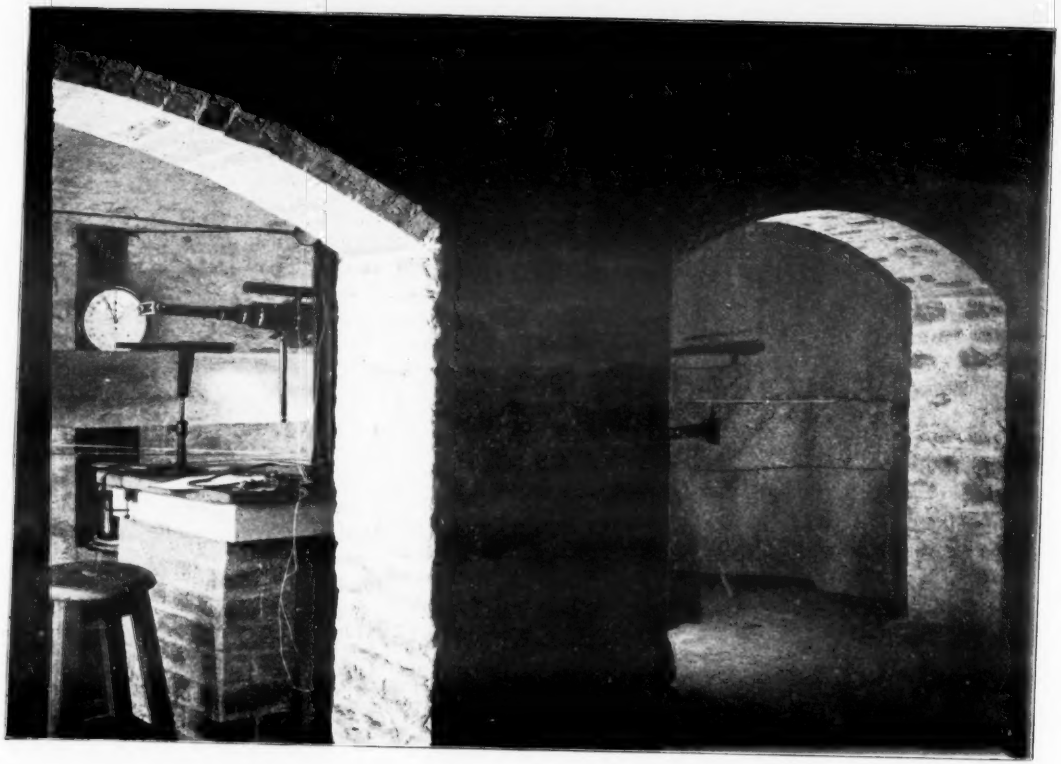
If no ellipsograph is at hand, the points of intersection of the parallels of latitude with the meridians may be computed and plotted according to the method explained at length in the second article (January number, page 252). The formulæ are $a = \cos \varphi$, $b = \cos \varphi \sin \delta$, $d = \sin \varphi \cos \delta$, $\xi = a \sin \tau$, $d - \eta = b \cos \tau$. The values of ξ and $d - \eta$ are computed by assigning to φ and τ values for every ten degrees from 0° to 90°. This will give about 72 quantities to compute and over 300 to plot. The computation may be performed very rapidly, but the plotting is tedious. It may be abridged by taking φ and τ only for every 20 degrees and drawing the intermediate ellipses by estimation, or by procuring or constructing some form of coördinate paper. This latter method may again be abridged and made very practical by ruling a rectangle of squares of tenths, twentieths, fiftieths, or even hundredths of the radius between the limits $+ 1.000$ and $- 1.000$, and $+ \sin \delta$ and $- \sin \delta$. The ruling ought to be done very carefully on a second piece of paper with a proper selection of heavy,

light and dotted lines. The diagram to be constructed (Fig. I or II) may then be placed over this paper in such a way that the indicated value of d will fall on the centre of the rectangle of squares and its longer sides will be parallel to the axis of X. The points of the ellipses, that is, the corresponding values of ξ and $d - \eta$, may then be plotted very rapidly without the use of dividers. But if much work of this kind is to be done, it will certainly pay to construct or procure an ellipsograph.

The Path of the Penumbra. The path of the Moon or penumbra on Fig. II is plotted by using the coördinates, x and y, given in the Ephemeris on page 415. This may be done in either of two ways. The first is to plot the same two points A and B, at $1^h\ 0^m$ and at $6^h\ 0^m$ Greenwich Time, which we used in locating the Moon's path on Fig. I in our second article (page 253), to draw a straight line through them, and to subdivide the distance between A and B into five equal parts or full-hour positions, and these again into sixths or ten-minute spaces. The second method is to plot every ten-minute or at least every hourly position directly by means of its coördinates, x and y, in the Ephemeris, and then to draw one straight line through all of these points. The Moon's positions at the full hours may be marked in Greenwich Time as the Ephemeris gives it, or more conveniently in Central Standard Time by subtracting $6^h\ 0^m$, that is, by writing VII to XII A. M. in place of 1^h to 6^h. The equation of time is not used here, nor is the Greenwich longitude of any given place, because the data we are using are given in absolute time and apply to the whole Earth. For this reason the marks indicating the hourly and ten-minnte positions of the Moon on its path on Figs. I and II of our present article are somewhat shifted from those given in Fig. I of the second article. In the figures of the present article the time of the Moon's crossing the axis of Y, that is, of its conjunction with the Sun (or its conjunction with the Earth as seen from the Sun) is $10^h\ 0^m$ A. M. Central Time ($4^h\ 0^m$ Greenwich Time, Eph. page 412), while in the former article it was $9^h\ 53^m$ A. M. St. Louis apparent solar time (see page 253).

With the Earth's disk and the path of the penumbra thus prepared as in Fig. II, we are ready to begin the construction of our chart.

PLATE V.



General View of Protected Corner, on Right. Clock, Observing Stool, Etc., on the Left.

Photographed by C. V. Boys for Popular Astronomy.

THE NEWTONIAN CONSTANT OF GRAVITATION.*

C. V. BOYS.

I have already stated that two measurements, viz., the horizontal distances between the axles of the wires which support the lead balls, and of the fibres which support the gold balls, must be made with the highest degree of accuracy attainable, for on these the result directly depends. In order to accomplish this I had to design a special instrument, an optical compass, which is illustrated in Fig. 4. This is an arrangement which rests upon the lid of the apparatus on the circular V-groove seen in Fig. 1†, so that it can rotate without shake. Upon the lower framing rests the focussing slide, and on this a pair of traversing slides, each carrying a microscope in one or other of three grooves. The two traversing slides are drawn together by a spring, and can be separated by a screw cone, forming a very delicate fine

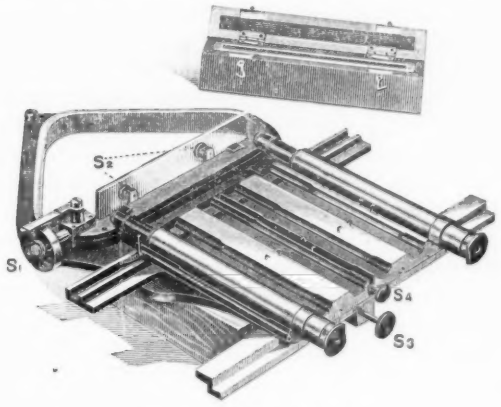


FIG. 4. OPTICAL COMPASS.

adjustment. This is operated by the screw-head S_1; S_3 is a focussing screw giving a fine adjustment to the focussing slide. S_2 is two parallelising screws, the purpose of which is to bring the microscopically divided glass scale into focus at each end simultaneously. S_4 is a micrometer screw-head, which is employed to push the scale bodily to the right by measured amounts. The two microscopes are focussed upon, say, the right sides of the wires, the focussing slide is then withdrawn, leaving them rela-

* A lecture delivered before the Royal Institution of Great Britain, June 8, 1894. Continued from page 175, Vol. III.

† See page 170, Dec. No., 1895.

Photographed by C. V. Boys for POPULAR ASTRONOMY.

tively unchanged, and the microscopic scale is then put in its place. The distance from wire to wire is thus transferred directly to the scale, and the fractional part of any one division of 1/100 inch is all that has to be referred to and measured by the screw. Every slide in this apparatus is geometrically arranged, so that the movements are all perfectly free, unconstrained and without shake. In measuring the distance between the fibres, which must be done while they are freely suspended, so that a force of a millionth of the weight of a grain will give them a considerable motion, means have to be provided to exclude draught, which yet must not interfere with the apparent distances of the fibres. No microscope cover-glass is any use for this purpose. It is sure to be prismatic, and when inserted between the microscope and an object it will certainly cause it to shift its apparent position. A piece of clear mica is perfect in this respect, no movement, even with a high power, being visible. I mention this as it well illustrates the sort of trap that is ever set for the experimentalist. If I had not been aware of this, and had used, as would be natural, a window of microscope cover-glass, then each fibre would have appeared as definitely in its place as before, but the place would have been wrong, perhaps by 1/1000 inch, and thus a consistent error affecting all the experiments alike would have been introduced, and no multiplication of observations or taking of means would have eliminated it. It is on this account that it is so important in experimental work to vary the conditions in every way, so as to discover unsuspected consistent errors.

The microscope scale was made by Zeiss, and is a most perfect example of scale construction. In order to test the accuracy and find the errors of the scale, I took advantage of my visit to Cardiff for the meeting of the British Association, to compare it with a series of Whitworth standard bars on Prof. Viriamu Jones's very perfect Whitworth measuring machine. For this class of work sunshine or dust give great trouble, but I was fortunate in having splendid weather for my purpose, as visitors will probably remember. It rained without ceasing during the two days I was making these measurements.

Having now very imperfectly described the apparatus and the place in which I have carried out my experiments, I will next show a series of photographs, which I took by magnesium light, to give a better idea of the appearance of the apparatus and its surroundings. Plate V is a view of the vault showing the clock, the eye-end of the big telescope, and the little telescope. In the distant corner is seen the felt screen with a long slit, through

which the scale and telescope can be seen from the mirror of the instrument. This, of course, is on the table behind the screen. Plate VI is a view of the corner itself, with the screen drawn back. The octogon protecting house, which surrounds the apparatus, is seen in position. Here again a slit is cut large enough to allow the scale and telescope to be seen from the mirror. Plate VII is a view of the instrument with the two halves of the octogon house separated. Here a further system of screens consisting of concentric brass tubes may be seen, but the lower one, which surrounds the window, has been removed and placed upon the table. The driving gear is also seen in this photograph, and a pipe coming from the screw under the instrument which holds the central tube, which pipe is also seen in Fig. 1. This enables me to control the motion of the mirror from the telescope without approaching the corner in which the apparatus is set up. This is done as follows: the back window at the level of the mirror is made of metal, with a hole in it in which is screwed a metal tube lightly filled with cotton-wool. This is not central, but opposite one end of the mirror. The pipe on the table does not fit the screw, but is merely bent up and enters it loosely. By gently drawing air from the end of the pipe at the telescope a very feeble draught is produced in the apparatus, for nearly all the required air is supplied by leakage round the pipe near the screw, very little entering through the window tube, in consequence of the resistance offered by the cotton-wool. In this way, if the mirror is moving it may be gently brought to rest without impact, or it may be given a swing of any desired amplitude. So perfectly does this work, that the mirror may be steadied very quickly so as to move through less than a scale division, an amount which corresponds to six or seven seconds of arc, or to a force of less than one thousand-millionth of the weight of a grain.

The operations for any complete experiment are fourteen in number. I do not intend to go through these seriatim, as time will not allow me to do so. It is sufficient now to say that the first eight are necessary to get the instrument and scale relatively fixed and adjusted, the vertical measures made, and generally all ready for operation 9, in which the optical compass is employed. This is a most important one, for not only are the horizontal measures made, on which so much depends, but in addition the planes of the wires and fibres are made identical, the corresponding scale reading is found, and any eccentricities are measured and may be corrected.

Plate VIII is a view of the apparatus with the optical compass

in position, and with the microscopes focussed upon the wires. They are then ready to be withdrawn by the focussing slide, so as to transfer the distances directly to the small glass scale, as already described.

When this is completed the proper windows are put in position, the screen tubes, the octagon house and the felt screens are all placed ready for operation 10, in which the deflections are measured, and the period with the balls is determined. As this is the operation in which variations of temperature produce so serious an effect, I prefer to leave everything undisturbed for three days, to quiet down. A few hours are quite useless for the purpose.

In operation 11 the period with the counter-weight in the place of the gold balls is measured; also the deflection, if any, due to the lid and lead balls upon the mirror alone. This is only 1 10 division, but its existence is certain. In the later operations the deflections, if any, due to the lid alone on the mirror and gold balls, are separately determined. Neither of these can be detected. The actual elongation of the fibre may also be observed at this stage, but this is of interest only as bearing on the elastic properties of quartz fibres under longitudinal strain.

Before I come to the treatment of the observations, I should like to refer shortly to the kind of perfection of conditions which by the employment of every practicable refinement that I could devise, I have succeeded in obtaining. Taking experiment 8 as an example, favorable in that the conditions were good, i. e. I was not badly disturbed by trains, wind, or earth tremors, I give the worst and the best sets of four points of rest obtained from six elongations. They were:—

Worst set + position.	Best set — position.
24493	20795.4
24493	20795.7
24493.5	20795.4
24492	20795.5
(24491.7)*	
24492.9 mean.	20795.5 mean.

Taking all the mean points of rest, as determined above, in groups of three to eliminate slow shifting, if any, of the points of rest, the series of deflections were:—

3696.5
3696.6
3696.0
3696.8

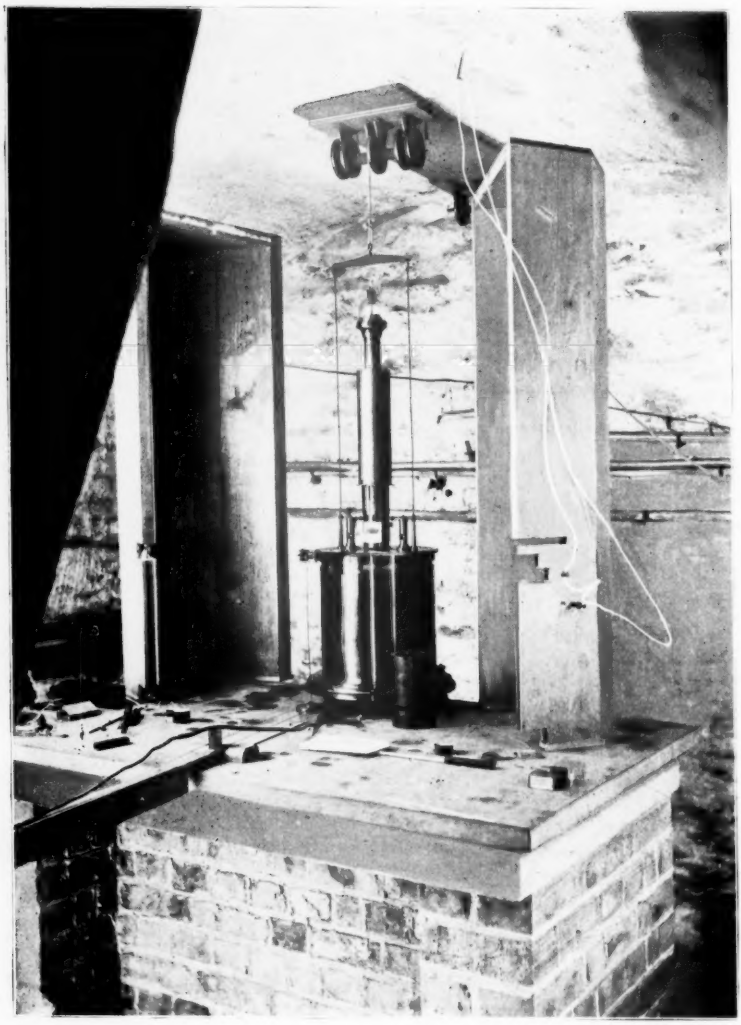
* Disturbed by trains.

PLATE VI.

NEARER VIEW OF PROTECTED CORNER, CURTAIN RAISED. INSTRUMENT IN OCTAGON HOUSE. OVERHEAD PULLEY VISIBLE.

Photographed by C. V Boys for POPULAR ASTRONOMY.

PLATE VII.



THE TWO HALVES OF THE OCTAGON HOUSE, SEPARATED TO SHOW THE INSTRUMENT.

Photographed by C. V. Boys for POPULAR ASTRONOMY.

(Interval of one hour, in which oscillations of large amplitude were observed for period.)

(3697.7)
3696.0

Immediately after the oscillations of large amplitude, which in this case at the end were rather badly disturbed by trains or otherwise, a rather different deflection was observed, but not seriously different. As examination of the figures shows only one anamolous point of rest immediately after the large amplitude disturbance, I feel justified in rejecting the only discordant figure, and in taking the mean of the rest as the true deflection. The unit in this case is 1/10 division. It corresponds to an angular movement of 1/280,000, i. e. about three-quarters of a second of arc. Now a calculation of the angular twist due to a rotation of the air based upon the period, the moment of inertia, and the logarithmic decrement, shows that if the air in the tube were made to whirl round at the rate of one turn in six weeks, so that the air would blow past the gold balls at the rate of one inch in a fortnight, the deflection produced would be 1/10 division, an amount which is greater than the uncertainty of the deflection on this particular night. Again, an examination of the points of rest through the night in the positive and in the negative positions shows a very small steady creep, the same in each case. Creepage of this sort has been, I believe, mentioned as a defect of quartz fibres. When it gives trouble it is due to draughts, as already explained, or to imperfect attachment of the fibres.* In the present instance the creepage observed corresponds to a surface rate of movement on the fibre of a millionth of an inch a month.

An examination of the mobile system of the beam and suspended gold balls, of which I exhibit a greatly enlarged and working model, at once shows that all the parts are capable of independent movement to an apparently perplexing degree. This in the theory of the instrument I have treated provisionally as a rigid system, moving all as one piece, which it certainly does not seem to be. For instance, the lead balls, by their attraction of the gold balls, pull them out of the perpendicular, so that their distance from the axis is greater than that given by measurement by the optical compass. The error amounts, in the case of the lower ball, when the lead is at its nearest points to 1/10,000,000 inch, and I have not taken any notice of it. When the beam is oscillating through so great an angle as 100,000 units the centrifugal force only makes the gold ball move out four times as much, and I

* See my paper on 'Attachment of Quartz Fibre,' Phil. Mag., May 1894.

have taken no notice of that. Again, when the mirror is under acceleration by the fibre, the gold balls, hanging 5 and 11 inches below, do not follow absolutely; they must lag behind, and so affect the period. Now in this case the gold balls are suspended in a manner which is dynamically equivalent to their being at the end of a pendulum 5¾ miles long, the shortest equivalent pendulum that has ever been employed in work of this kind; but short as it is, I have not thought it worth while to be perturbed by an uncertainty of a few inches. There is one point which in some of the experiments only has amounted to a quantity which I do not like to ignore. It is due to the torsional mobility of the separate fibres, about which each gold ball hangs, allowing them in their rotation to slightly lag behind the mirror. As I did not see how to allow for it, I applied to Professor Greenhill, who immediately told me what to do, and who, with Professor Minchin, spent a day or two in the country, covering many sheets of paper with logarithms, in finding and solving for me the resulting cubic equation. The correction on this account is 1/7850 on the stiffness of the torsion fibre.

There are four remaining corrections depending on the fact that besides the gravitating spheres there are the ball holders and supporting wires and fibres, all of which produce small but definite disturbances in the gravitation. These are all calculated and allowed for. They are:—

Disturbances due to brass holders of lead balls.....	1/7320
" " copper " gold "	1/265,000
Attraction of lead balls for quartz fibres.....+	1/200,000
" gold " phosphor-bronze wires.....—	1/115,000

Then in experiment 9 gold cylinders were employed. Mr. Edser, of the Royal College of Science, calculated for me the correction to be applied if they were treated as spheres; this amounted to 1/2300.

I have already mentioned that experiment 8 was made under more than unusually quiet conditions. Such extreme quiet is desirable, that I manage to reserve Sunday nights, from midnight to six or eight o'clock in the morning, for observations of deflection and period. All the other operations can be carried on in the day-time. Sunday is the only night that is suitable, as the railway companies spend every other night shunting and making up trains about a mile away, and this causes such a continuous clatter and vibration, that hours of work may be lost. A passing train does not seem so injurious; but, fortunately for me, most of the observations were make during the coal strike, and fewer

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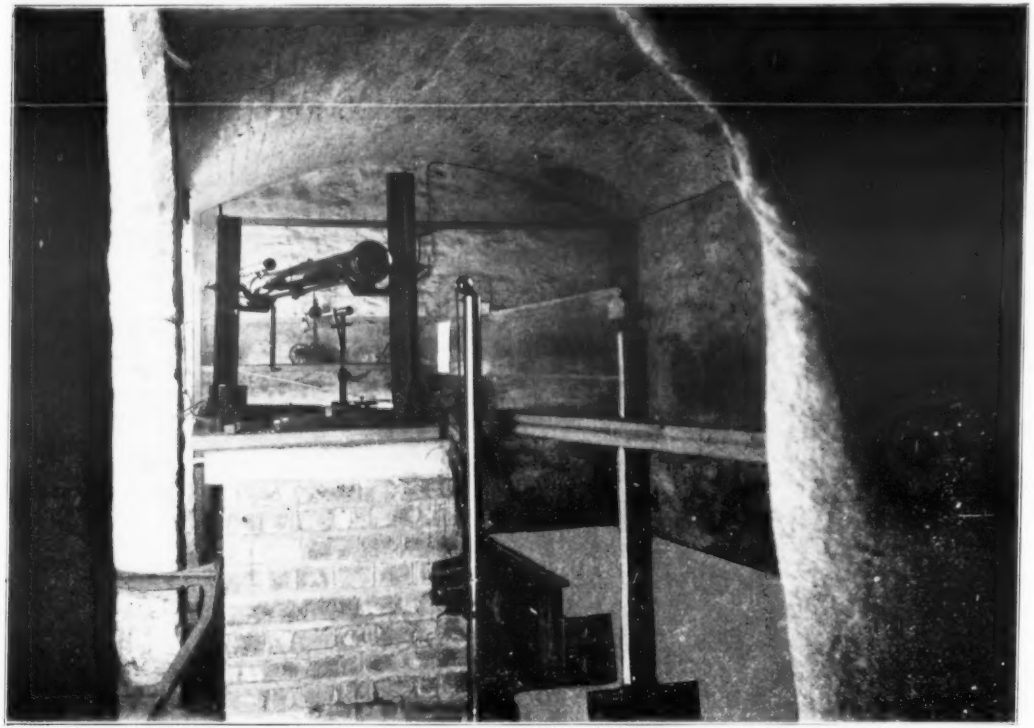
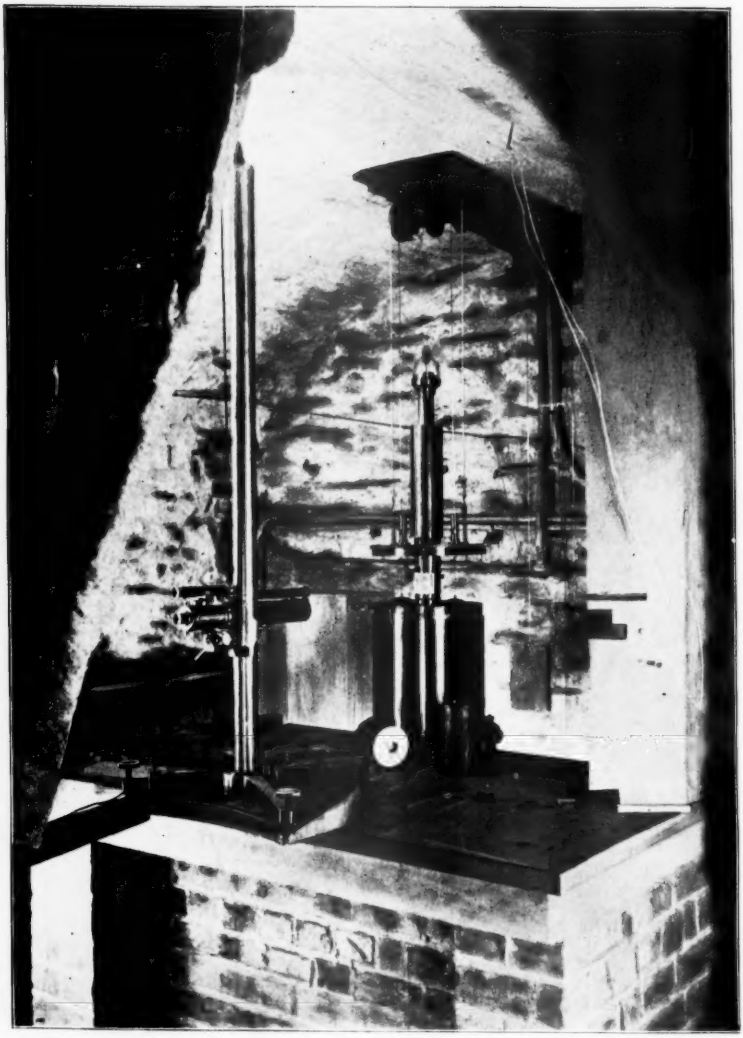
PLATE IX.



View from Protected Corner up the Cellar, to the Scale at Far End. Telescope in Position.

Photographed by C. V. Boys for Popular Astronomy.

PLATE X.



VERTICAL MEASURES CATHETOMETER READING UPPER SURFACES OF SUSPENDED LEAD BALLS.

Photographed by C. V. Boys for POPULAR ASTRONOMY.

trains than usual were running. However, though I may escape from the rattling traffic of St. Giles by working at night, and on Sunday nights am not so badly affected by the trains, I am still not sure of quiet even when there is no wind. For instance, at a quarter to four on Monday morning, Sept. 10, 1893, I was recording chronographically the passage of every ten divisions. Everything was quite quiet, and at the particular moment the marks on the drum recurred at intervals of about three seconds. Suddenly there was a violent non-vibrating lurch of fifteen divisions, or 150 units, which is enormously greater than anything that either trains or traffic could produce; of course I could make no further record. The time of the last mark was, allowing for the known error of the clock, $15^h\ 44^m\ 14^s.3$. This was entered the same day in my note-book as an earthquake, and in Tuesday's *Standard* I read an account of a violent earthquake in Roumania at about the same time. Mr. Charles Davison informs me that the shock was recorded at Bucharest at $15^h\ 40^m\ 35^s$, but that the epicentrum must have been some distance from there. Exact particulars, it seems, cannot be obtained. Though it would appear that the rate of travel of the shock is unusually high, there never was any doubt that what I observed was an earthquake, and it is practically certain that it was the Roumanian earthquake.

Owing to the viscosity of the air, which limits the time during which an observation for period can be made to about 40 minutes, on account of the resistance that the slowly moving mirror and gold balls experience in their passage through it, I made one experiment with a view of reducing this difficulty, by the use of an atmosphere of pure dry hydrogen gas, which possesses a viscosity only half that of air. I found that on this account a great advantage could be gained; but this was more than counterbalanced by the difficulty of getting up a sufficient swing in the gas, and of efficiently controlling the mirror. At the same time, I think that if I had had time to provide means for feeding the gas into the tube without entering the corner, and at the same time were to prevent diffusion at the lower screw, that a little trouble in this direction would be well rewarded. Meantime I found within the limits of error, which were greater than without the hydrogen, that the deflection and the period corrected for the diminished damping were the same. The chief interest of this experiment lies in the fact that it revealed an action unknown to me, and I believe to others, that a thin plane glass mirror, silvered and lacquered on one side, definitely bends to a small extent, becoming slightly convex on the glass side when in hydrogen, and

instantly recovers its form when surrounded by air again. This happened many times, producing a change of focus in the telescope of about ⅝ inch. I do not offer any explanation of the fact.

There is an observation which should be of interest to elasticians. In experiments 4 to 8 the torsion fibre carried the beam mirror and the .25-inch gold balls, weighing, with their hooks and fibres, 5.312 grammes. In experiment 9, gold cylinders were substituted, weighing, with their hooks and fibres, 7.976 grammes. The weight of the mirror was .844 gramme. In consequence of the small increase of load the torsional rigidity of the fibre fell more than 4 per cent., an amount far too great to be accounted for by the change of dimensions, even if Poisson's ratio were as great as ½. There is no doubt about the great reduction in stiffness, for this figure is one of the factors in the final expression for G, which does not show a change of more than 1 part in 1570. [TO BE CONTINUED.]

SCIENCE BY CO-OPERATION.

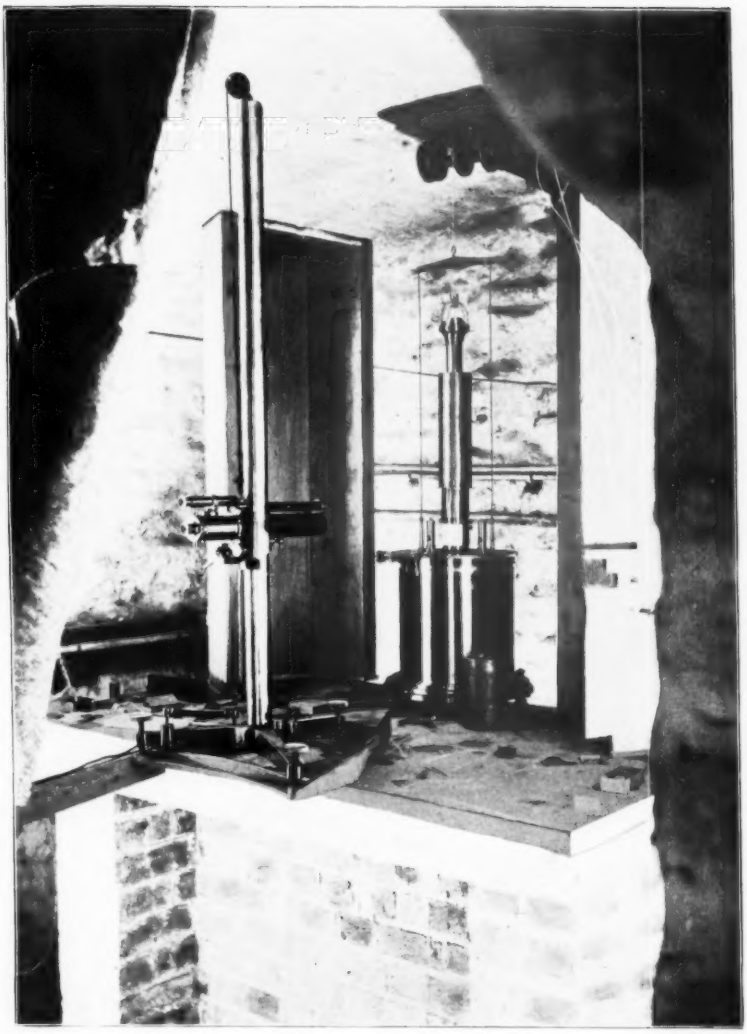
THOMAS LINDSAY.

FOR POPULAR ASTRONOMY.

Those who have at heart the popularizing of scientific studies must be highly gratified at the large measure of success which is gradually being attained amongst English speaking people at least; when we find in the "latest dispatch" column of our daily newspaper an account of the very last results in experimental philosophy, it certainly looks as if the news gatherers were becoming broad in their views as to what would interest their readers. They seem to clearly recognize that when the news market is dull in politics or business there is an inexhaustible mine of scientific notes to draw upon. No one thing has brought this about—it is the result of an evolutionary process, beginning somewhere in the era of the common school and cheap books. But now that it is brought about, now that we are in a scientific age, we should take advantage of everything that will in the least degree tend towards strengthening the position, and we may hope that eventually it will come to be recognized as sound philosophy, that the pursuit of knowledge for its own sake moulds character and directs action.

It becomes necessary then to be just a little bit aggressive—to organize, reach out and gather in, wherever material may be

PLATE XI.



VERTICAL MEASURES. CATHETOMETER READING SUPPORTS OF LEAD BALLS.

Photographed by C. V. Boys for POPULAR ASTRONOMY.

found. Societies can be formed for pretty nearly every object that will bring men together at all: there are perhaps no persons of intelligence who are not in some way interested in the wonders of astronomy; therefore our duty is clear. If it is only a little group that will meet occasionally to observe such celestial objects as may be visible through a field glass, that is something, that is sowing the seed. In a little while they will become dissatisfied with their humble apparatus and "ask for more." It is a curious fact that in this department of human desire people always do ask for more,—who ever found the veriest amateur that did not long for "more light," more knowledge, when once started on the path of nature study?

Not only does the forming of associations strengthen the cause of the whole body, it does something for the individual. For instance, Mr. A takes some interest in things not exactly connected with the routine of his daily life, and is considered a little "odd"; Mr. B is of the same ilk and he too is thought to be just a trifle "peculiar"; but there is Mr. C and Mr. D and so on down the alphabet, they cannot all be "odd!" They must even up somewhere, and so in truth by association they will, until by mildly aggressive methods the tide of opinion may be so turned that they will be considered odd, who have no thoughts, aspirations, desires, beyond what most immediately surrounds them. How to bring about this state of affairs is a problem for solution.

Some of the difficulties in the way of gathering in we experience early. For instance, one of our friends will, with becoming modesty, disclaim any knowledge of astronomy except just a very little—elementary—and thinks he would be out of place among a group of scientists. Now it is really surprising how hard it is to make him believe that we lay no claim to such a dignified title. We protest that our own knowledge is quite in the elementary stage, and that we want to gather in more of the same class on the principle that "misery loves company." But no, "Why you have Mr. A among you!" "True, but he is only one." "O well, there is Mr. B, I saw an account of a paper he read the other day." "About comets?" "Yes, and what they are made of and all that." "O come now, that was merely a collection of opinions, brought together by request, there was nothing extra about that, you could have done the same thing yourself." "I, O no," and so on.

There is, however, one little difficulty to be met as best it can; our friend who puts such a modest limit upon his acquirements may, if he becomes connected with an association already formed,

find that the proceedings are sometimes dry—to him. Now this simply cannot be helped, at the time, it will right itself by and by. A society formed for scientific recreation will not be an assemblage of specialists, and it is quite impossible that all could be interested in the same branches, and astronomy is so wide—so very wide. This point may be overlooked also in forming a judgment regarding a book or periodical. The great monthlies of Europe and America have millions of readers, but, select even your favorite magazine, are you interested in everything you find between the covers?

Another type which the enthusiast will find when he goes abroad seeking whom he may gather in, is the man whose daily occupation is in the world of science. For him it is scarcely a recreation to meet with amateurs for scientific discussion, it is too much like work. Yet there is always something to be learned, amateurs ask some strange questions at times, and these may set one a-thinking! Not only, however, is the known professional exposed to volleys of curious questions, the amateur in his turn, being recognized as knowing something has occasion to keep pretty well posted on current events in the world of discovery and to have ready explanations for everything mysterious. And not this alone, he will meet often enough with some one possessed of a theory either startlingly new, perhaps ridiculous, or old as the hills and as indestructible. One has to exercise a little tact in the latter case; it is a good plan to mention the name of some great man who you believe, "held views somewhat similar to those you have expressed—I think I can give you a reference or two which you might look up, they will strengthen your position," and so on. Which of us indeed has not at some time made a brilliant discovery only to find that the text books had it? We were pleased with ourselves for being so clever, and must have a little consideration for others. Such people we want to gather in, their knowledge of what has been done in scientific fields is limited, ours is not immense, we can at least get them to follow us in one respect and read.

But the one with a new theory is more difficult to handle. We are getting into such a stream of discovery that we really hesitate to say anything is unsound until we have thoroughly investigated it and it is not a very easy matter to do that. Yet if we are on a foraging expedition we must answer quickly else our friend will put us down as not knowing any more than the "law allows us," in which by the by he is most probably correct.

An incident in my own experience occurred recently which I

may be allowed to relate in explanation. I met a gentleman whom I knew slightly as one interested a little in astronomy. He was moreover a strong Salvation Army man. (There is no reason why these should not go together). "Had I been reading much lately?" "O yes, I am always doing that you know." "Well tell me now—I had an argument with an infidel lately—has Jupiter an upper sea?" Now a man is never properly cornered till he is asked a question like this in broad daylight, in the middle of a business street. Yet if the question had been asked me some time ago I would have answered in a moment. As it was however, having unfortunately passed the age when I knew everything, I hesitated—and was lost. "Well—I believe—that there is—abundant proof—that—of—of the existence—of—a water vapor—in the atmosphere of Jupiter." "Yes, yes, but I mean a sea of water all around it like a ring, same as there was around the Earth before the flood," and so on. Well, never having used any astronomical instruments to prove the story of the flood I hesitated to commit myself and my friend left me with the remark that he would be glad to look in occasionally on a certain society "if we were doing any good work" in the way of conversions I suppose!

But no matter what difficulties there may be in the way it is the duty of every lover of science to endeavor to bring men together. Little knots of readers formed here and there will have an influence for good; no town of any size will lack for material and if only people can be brought to see that it is not necessary to be original discoverers or great mathematicians to enjoy the pleasures which astronomy affords, there will certainly spring up in more abundance those associations which by the very nature of their objects are among all, the least marked by internal troubles and dissensions.

TORONTO.

ON THE RESEARCHES MADE AT THE OBSERVATORY OF MADISON BY MR. G. C. COMSTOCK, CONCERNING ABERRATION AND REFRACTION. Note by M. Loewy.*

"The volume published by the Observatory of Madison, and of which I am asked to speak to the Academy, contains an important memoir by Mr. G. C. Comstock 'On the investigation of aberration and atmospheric refraction.' He has made use of optical

* Comptes rendus des séances de l'Académie des Sciences, May 26, 1896. Translated from the French by Dr. H. C. Wilson.

apparatus the principles of which I have indicated in different communications to the Academy, which date back now some years, but to which he has added some original and important modifications.

"The method which I proposed required the employment of a mirror formed by two reflecting surfaces placed before the objective of a telescope. This arrangement permits the measurement of the angular interval between two stars, situated in very different regions of the sky, with considerable precision, independent of any hypothesis on the constancy or variability of the latitude. It is possible thus to determine directly several fundamental constants of astronomy, notably those of aberration and refraction. I have, at the Paris Observatory, made an application of this method to the investigation of the constant of aberration.

"The process which we have used is purely differential, that is to say, it rests upon the measurement, on the same evening, of the arcs which separate two pairs of stars. Mr. Comstock desired to extend the application of the method in making it furnish the absolute values of the distances. He was thus led to greatly modify the arrangement of the apparatus and the manner of operating it. Thus, instead of two reflecting surfaces, polished on the same block of glass and therefore invariably fixed with reference to each other, Mr. Comstock has placed before the telescope three plane mirrors, each susceptible of independent adjustment. The stars associated are not 90° but 120° apart on the celestial sphere. Each of these is seen, not through a half of the objective, but through a circular aperture, of which the diameter does not exceed 5cm.

"This arrangement, deduced by very ingenious theoretical reasoning, renders possible the absolute measure of an arc approximating 120° on the celestial sphere. It permits also the elimination of the error which results from imperfect focussing, an error the law of which was brought to light by Mr. Comstock in a preliminary investigation. But these advantages are gained at the price of very serious practical difficulties, imposed by the physical conditions of the problem, and which seem of a nature to limit in their application the beautiful conceptions of Mr. Comstock. The measures of the distances must necessarily be made at low altitudes; the influence of refraction becomes, in consequence, very sensible and it is found necessary to put first the study of refraction and of aberration. Mr. Comstock is thus seen compelled to discuss and elucidate different points which interest general astronomy. For instance, the influence of the hygrometric state of

the air upon the refraction, that of the colour of the stars, influences which are generally neglected, for example by Laplace, seen quite clearly to emerge from the observations made at Madison.

"These same series bring a confirmation to the numbers found in the physical laboratories for the index of refraction and the coefficient of expansion of the atmospheric air. They accord very well with the mean refractions based upon the work at the Observatory of Poulkova, even in indicating as probable a small variation of the constant of refraction having the year as its period. Another conclusion, already rendered probable by different researches, consists in the fact that the meridian instruments appear to give values systematically too great for the right ascensions of faint stars, this effect attaining a possible value of 0.009^s per magnitude of the star. A curious result of these studies is the existence of a personal equation in the measurement of distances, the correction for which varies as the square of the interval measured. The thorough discussion which Mr. Comstock has given leads him to regard this phenomenon as real and gives as definitive for the constant of aberration, the figures 20″.44, very near to those which were found a half a century ago, by W. Struve. This value is in very satisfactory accord with that furnished by our own investigations. Neither depend in any way upon hypotheses made on the law of the variability of latitude.

"The sagacity and perseverance of which Mr. Comstock has given proof in the course of these difficult researches seem to me to designate his work as peculiarly worthy the attention of the Academy."

The Newtonian Constant of Gravitation.—We have held back the remainder of Professor C. V. Boys's lecture on "The Newtonion Constant of Gravitation" for several months, until we could procure photographs of the instruments used, to illustrate fully the several steps that were taken in this important study. Professor Boys very kindly furnished us twelve fine photographs (the instruments in place) taken by the aid of magnesium light and six of these illustrations are given in this number. We have purposely reserved Plate VIII until next time.

We have also asked Professor Boys to favor our readers by giving a detailed statement of his method of reducing his observations by which his value of G is obtained. This part of his work is not given in the lecture which we are reprinting. There is some reason for this, for prominent American scholars are apparently not agreed as to exact methods of procuring the value of G.—Ed.

PRACTICAL SUGGESTIONS.

THE SIDEREAL EPHEMERIS.

J. MORRISON, M. A., M. B., PH. D.

FOR POPULAR ASTRONOMY.

If the fixed stars were referred to some invariable plane and line of reference, their places would vary only by the amount of their own proper motion in space, and the computation of their coördinates would be comparatively an easy matter, but in order that they may be available for the purposes of astronomy, navigation and geodesy, they must be referred to the movable equator and equinox, that is to say, to the true equator and equinox of the date, for which their positions are required. Their R. A. and Decl. from day to day will therefore be affected by the three astronomical corrections—precession, nutation and aberration, and the computation of their positions will accordingly be laborious, tedious and troublesome. The place of a star referred to the *mean* equator and equinox of *any date*, is its *mean* place for that date; that referred to the *true* equator and equinox, is its *true* place and that in which it is seen, referred to the true equator and equinox, its *apparent* place. The true place is equal to the mean corrected for *nutation*, and the apparent place is equal to the true, corrected for *aberration*. The true and mean places are found from the apparent by applying the same corrections with their signs changed.

The mean R. A. and Decl. of the principal stars for the beginning of each year or rather for the beginning of the fictitious year, that is when the Sun's mean longitude is 280°, are given on pages 293 to 301 of the American Ephemeris, and in the adjacent columns are given the annual variation in R. A. and Decl. by means of which the mean place for any other date may be easily found. The apparent places for the upper transit at Washington are given for every tenth day of the year on the following pages together with the variation at each date. The apparent place, however, must not be confounded with the observed place or the place in which we actually see the stars. The latter is affected by two other corrections, viz: diurnal aberration and refraction. The former depends on the latitude of the place of observation and the declination of the star and is so small that it may generally be neglected except for stars very near the pole when the R.A. at the time of transit will be increased by $0^{sec}.0216 \cos \varphi \sec \delta$, while the latter depends on the altitude or zenith distance of the

star at the place of observation. Of course neither of these can be taken into consideration in the construction of an ephemeris which is always computed for the centre of the Earth, the general station from which all astronomical phenomena are supposed to be viewed.

If α and δ denote the *mean* R. A. and Decl. at the beginning of the fictitious year and α' and δ' the apparent R. A. and Decl. at any subsequent date τ expressed in years or fractions of a year, we shall have,

$\alpha' = \alpha + \tau \times$ mean annual precession + nutation + aberration $+ \tau \times$ annual proper motion, and similarly for δ'.

The precession, nutation and aberration in R. A. and Decl. have already been investigated on pages 25-33. The proper motion is always very small and can be found in the star catalogues. It is deduced from observations continued during a long period, the longer the better. Substituting now the expressions for precession, nutation and aberration, we have

$$\begin{aligned}
\alpha' = \alpha &+ \tau\,(m + n \sin\alpha \tan\delta) && \text{(Precession)}\\
&+ \Delta I\,(\cos\omega + \sin\alpha \sin\omega \tan\delta) - \Delta\omega \cos\alpha \tan\delta && \text{(Nutation)}\\
&- h \sec\delta\,(\sin\alpha \sin\odot + \cos\alpha \cos\omega \cos\odot) && \text{(Aberration)}\\
&+ \tau\mu && \text{(Proper Motion)}\\
\delta' = \delta &+ \tau n \cos\alpha && \text{(Precession)}\\
&+ \Delta I \cos\alpha \sin\omega + \Delta\omega \sin\alpha && \text{(Nutation)}\\
&- h\,(\cos\odot \sin\omega \cos\delta + \sin\odot \cos\alpha \sin\delta\\
&\qquad - \cos\odot \cos\omega \sin\alpha \sin\delta) && \text{(Aberration)}\\
&+ \tau\mu' && \text{(Proper Motion)}
\end{aligned}$$

The values of ΔI and $\Delta\omega$ vary slightly from year to year and the three most important terms of each are given on page 27. More accurate values for the year 1900 are as follows:

$$\begin{aligned}
\Delta I = &- 17''.2574 \sin\Omega + 0''.2073 \sin 2\Omega - 1''.2695 \sin 2\odot\\
&+ 0''.1474 \sin(82^\circ + \odot) + 0''.0125 \sin(2\odot - \Omega)\\
&- 0''.0058 \sin(3\odot - 281^\circ.2) - 0''.0024 \sin 2(\odot - \Omega)\\
&+ 0''.0053 \sin 2(\odot - T') - 0''.2041 \sin 2\mathbb{D}\\
&+ ''.0677 \sin(\mathbb{D} - T') + \ldots.\\
\Delta\omega = &+ 9''.2240 \cos\Omega - 0''.0895 \cos 2\Omega + 0''.5506 \cos 2\odot\\
&+ 0''.0092 \cos(281^\circ.2 + \odot) - 0''.0067 \cos(2\odot - \Omega)\\
&+ 0''.0027 \cos(3\odot - 281^\circ.2) + 0''.0023 \sin T'\\
&+ 0''.0885 \cos 2\mathbb{D} + 0''.0181 \cos(2\mathbb{D} - \Omega) + \ldots.
\end{aligned}$$

and $h = 20''.4451$.

In these formulæ μ and μ' are the proper motions in R. A. and Decl., $\odot$ the Sun's true longitude, Ω the longitude of the Moon's

ascending node, ω the obliquity of the ecliptic, T′ the longitude of the Moon's perigee and ☽ the Moon's longitude.

Taking $\omega = 23^\circ\ 27'\ 8''$, substituting the values of Δl, $\Delta\omega$ and h, reducing and arranging the coefficients and restoring the values of m and n, we have the following :—

$$
\begin{aligned}
\alpha' = \alpha &+ \tau(46''.0907 + 20''.0410 \sin\alpha \tan\delta) && \text{(Precession)}\\
&- (15''.8318 + 6''.8682 \sin\alpha \tan\delta) \sin\Omega \\
&+ (0''.1902 + 0''.0825 \sin\alpha \tan\delta) \sin 2\Omega \\
&- (1''.1646 + 0''.5052 \sin\alpha \tan\delta) \sin 2\odot \\
&+ (0''.1352 + 0''.0488 \sin\alpha \tan\delta) \sin(82^\circ + \odot) \\
&+ (0''.0145 + 0''.0050 \sin\alpha \tan\delta) \sin(2\odot - \Omega) \\
&- (0''.0053 + 0''.0023 \sin\alpha \tan\delta) \sin(3\odot - 281^\circ.2) \\
&- (0''\ 0022 + 0''.0009 \sin\alpha \tan\delta) \sin 2(\odot - \Omega) \\
&+ (0''.0049 + 0''.0021 \sin\alpha \tan\delta) \sin 2(\odot - \mathrm{T}') \\
&- (0''.1872 + 0''.0812 \sin\alpha \tan\delta) \sin 2\,☽ \\
&+ (0''.0621 + 0''.0269 \sin\alpha \tan\delta) \sin(☽ - \mathrm{T}') && \text{(Nutation)}\\
&- 9''.2240 \cos\Omega \cos\alpha \tan\delta \\
&+ 0''.0895 \cos 2\Omega \cos\alpha \tan\delta \\
&- 0''.5506 \cos 2\odot \cos\alpha \tan\delta \\
&- 0''.0092 \cos(281^\circ.2 + \odot) \cos\alpha \tan\delta \\
&+ 0''.0067 \cos(2\odot - \Omega) \cos\alpha \tan\delta \\
&- 0''.0027 \cos(3\odot - 281^\circ.2) \cos\alpha \tan\delta \\
&- 0''.0023 \sin\mathrm{T}' \cos\alpha \tan\delta \\
&- 0''.0885 \cos 2\,☽ \cos\alpha \tan\delta \\
&- 0''.0181 \cos(2\,☽ - \Omega) \cos\alpha \tan\delta \\
&- 20''.4451 \cos\alpha \cos\odot \cos\omega \sec\delta && \text{(Aberration)}\\
&- 20''.4451 \sin\alpha \cos\odot \sec\delta && \text{(Aberration)}\\
&+ \tau\mu && \text{(Proper Motion)}
\end{aligned}
$$

and

$$
\begin{aligned}
\delta' = \delta &+ 20''.041\ \tau \cos\alpha && \text{(Precession)}\\
&- 6''.8682 \cos\alpha \sin\Omega \qquad + 9''.2240 \sin\alpha \cos\Omega \\
&+ 0''.0825 \cos\alpha \sin 2\Omega \qquad - 0''.0895 \sin\alpha \cos 2\,\Omega \\
&- 0''.5052 \cos\alpha \sin 2\odot \qquad + 0''.5506 \sin\alpha \cos 2\,\odot \\
&+ 0''.0488 \cos\alpha \sin(82^\circ + \odot) + 0''.0092 \sin\alpha \cos(281^\circ.2 + \odot) \\
&+ 0''.0050 \cos\alpha \sin(2\odot - \Omega) - 0''.0067 \sin\alpha \cos(2\odot - \Omega) \\
&- 0''.0023 \cos\alpha \sin(3\odot - 281^\circ.2) && \text{(Nutation)}\\
&\qquad + 0''.0027 \sin\alpha \cos(3\odot - 281^\circ.2) \\
&- 0''.0009 \cos\alpha \sin 2(\odot - \Omega) + 0''.0023 \sin\alpha \sin\mathrm{T}' \\
&+ 0''.0021 \cos\alpha \sin 2(\odot - \mathrm{T}') + 0''.0885 \sin\alpha \cos 2\,☽ \\
&- 0''.0803 \cos\alpha \sin 2\,☽ \qquad + 0''.0181 \sin\alpha \cos(2\,☽ - \Omega) \\
&+ 0''.0269 \cos\alpha \sin(☽ - \mathrm{T}') \quad \ldots\ldots \\
&- 20''.4451 \cos\omega \cos\odot (\tan\omega \cos\delta - \sin\alpha \sin\delta) && \text{(Aberration)}\\
&- 20''.4451 \sin\odot \cos\alpha \sin\delta && \text{(Aberration)}\\
&+ \tau\mu' && \text{(Proper Motion)}
\end{aligned}
$$

From these formulæ the apparent R. A. and Decl. of any star may be computed, but the computation in this form would be exceedingly laborious and troublesome and therefore we have recourse to the following elegant transformation invented by the

illustrious Bessel. In the formula for α', it is at once seen that the numerical coefficients in the terms involving sin Ω, sin 2Ω, etc., are very nearly in the ratio of m to n, that is of 46″.0907 to 20″.0410—a circumstance which is not accidental but results from the theory of nutation. Since

	$n = 20''.0410$	and	$m = 46''.0907$
Put.....	$nk = 6.8682$	and	$mk + g = 15.8318$
	$nk_1 = 0.0825$		$mk_1 + g_1 = 0.1902$
	$nk_2 = 0.5052$		$mk_2 + g_2 = 1.1646$
	$nk_3 = 0.0488$		$mk_3 + g_3 = 0.1352$
	$nk_4 = 0.0050$		$mk_4 + g_4 = 0.0145$
	$nk_5 = 0.0023$		$mk_5 + g_5 = 0.0053$
	$nk_6 = 0.0009$		$mk_6 + g_6 = 0.0022$
	$nk_7 = 0.0021$		$mk_7 + g_7 = 0.0049$
	$nk_8 = 0.0812$		$mk_8 + g_8 = 0.1872$
	$nk_9 = 0.0269$		$mk_9 + g_9 = 0.0621$

Substituting in the preceding formulæ for α' and δ' and factoring, we have

$$\begin{aligned}\alpha' = \alpha &+ [\tau - k\sin\varpi + k_1\sin 2\varpi - k_2\sin 2\odot + k_3\sin(82^\circ + \odot)\\
&+ k_4\sin(2\odot - \varpi) - k_5\sin(281^\circ.2 + 3\odot) - k_6\sin 2(\odot - \Omega)\\
&+ k_7\sin 2(\odot - \mathrm{T}') - k_8\sin 2\mathfrak{D} + k_9\sin(\mathfrak{D} - \mathrm{T}') + \ldots][m + n\sin\alpha\tan\delta]\\
&- [9''.2240\cos\varpi - 0''.0895\cos 2\varpi + 0''.5506\cos 2\odot\\
&+ 0''.0092\cos(281^\circ.2 + \odot) - 0.0067\cos(2\odot - \varpi)\\
&+ 0.0027\cos(3\odot - 281^\circ.2) + 0.0023\sin\mathrm{T}' - 0.0885\cos 2\mathfrak{D}\\
&- 0.0181\cos(2\mathfrak{D} - \varpi)]\cos\alpha\tan\delta\\
&- 20''.4451\cos\alpha\cos\odot\cos\omega\sec\delta\\
&- 20''.4451\sin\alpha\sin\odot\sec\delta\\
&- g\sin\varpi + g_1\sin 2\varpi - g_2\sin 2\odot + g_3\sin(82^\circ + \odot) + g_4\sin 2(\odot - \Omega)\\
&- g_5\sin(3\odot - 281^\circ.2) - g_6\sin 2(\odot - \varpi) + g_7\sin 2(\odot - \mathrm{T}') \ldots .\\
&+ \tau\mu\end{aligned}$$

and

$$\begin{aligned}\delta' = \delta &+ [\tau - k\sin\varpi + k_1\sin 2\varpi - k_2\sin 2\odot + k_3\sin(82^\circ + \odot)\\
&+ k_4\sin(2\odot - \varpi) - k_5\sin(3\odot - 281^\circ.2) - k_6\sin 2(\odot - \Omega)\\
&+ k_7\sin 2(\odot - \mathrm{T}') - k_8\sin 2\mathfrak{D} + k_9\sin(\mathfrak{D} - \mathrm{T}')]\, n\cos\alpha\\
&+ [9''.2240\cos\varpi - 0''.0895\cos 2\varpi + 0''.5506\cos 2\odot\\
&+ 0''.0092\cos(281^\circ.2 + \odot) - 0''.0067\cos(2\odot - \varpi)\\
&+ 0''.0027\cos(3\odot - 281^\circ.2) + 0''.0023\sin\tau' + 0''.0885\cos 2\mathfrak{D}\\
&+ 0''.0181\cos(2\mathfrak{D} - \varpi)]\sin\alpha\\
&- 20''.4451\cos\omega\cos\odot(\tan\omega\cos\delta - \sin\alpha\sin\delta)\\
&- 20''.4451\sin\odot\cos\alpha\sin\delta\\
&+ \tau\mu'\end{aligned}$$

The values of k, k_1, etc., g, g_1, etc., obtained by solving the preceding equations, are :

$k = 0.3427$	$g = 0.0360$
$k_1 = 0.0041$	$g_1 = 0.0006$
$k_2 = 0.0252$	$g_2 = 0.0028$
$k_3 = 0.0024$	$g_3 = 0.0230$
$k_4 = 0\ 0002$	$g_4 = 0.0030$
$k_5 = 0.0001$	$g_5 = 0.0000$
$k_6 = 0.00004$	$g_6 = 0.0001$
$k_7 = 0.0001$	$g_7 = 0.0001$
$k_8 = 0.00405$	$g_8 = 0.00045$
$k_9 = 0.00134$	$g_9 = 0.00023$

Substituting these values we finally have

$$\begin{aligned}
\alpha' = \alpha &+ [\tau - 0''.3427 \sin \varsigma + 0''.0041 \sin 2\varsigma - 0''.0252 \sin 2\odot \\
&+ 0''.0024 \sin (82^\circ + \odot) + 0.0002 \sin (2\odot - \Omega) \\
&- 0.0001 \sin (3\odot - 282^\circ.2) - .00004 \sin 2(\odot - \varsigma) \\
&+ 0.0001 \sin 2(\odot - T') - 0.00405 \sin 2\,\mathfrak{D} \\
&+ 0.00134 \sin (\mathfrak{D} - T')] [m + n \sin \alpha \tan \delta] \\
&- [9''.2240 \cos \varsigma - 0.0895 \cos 2\varsigma + 0''.5506 \cos 2\odot \\
&+ 0''.0092 \cos (281^\circ.2 + \odot) - 0''.0067 \cos (2\odot - \Omega) \\
&+ 0''.0027 \cos (3\odot - 281^\circ.2) + 0.0023 \sin T' + 0.0885 \cos 2\,\mathfrak{D} \\
&+ 0.0181 \cos (2\,\mathfrak{D} - \Omega)] \cos \alpha \tan \delta \\
&- 20''.4451 \cos \alpha \cos \odot \cos \omega \sec \delta \\
&- 20''.4451 \sin \alpha \sin \odot \sec \delta \\
&- 0''.0364 \sin \varsigma - 0''.0039 \sin 2\varsigma - 0''.0028 \sin 2\odot \\
&\qquad + 0''.0230 \sin (82^\circ + \odot) \\
&+ 0''.0030 \sin (2\odot - \Omega) - 0.00001 \sin (3\odot - 281^\circ.2) \\
&\qquad - 0.0001 \sin 2(\odot - \Omega) \\
&+ 0.0001 \sin 2(\odot - T') - .00045 \sin 2\,\mathfrak{D} + 00023 \sin (\mathfrak{D} - T') + \ldots \\
&+ \tau\mu
\end{aligned}$$

and

$$\begin{aligned}
\delta' = \delta &+ [\tau - 0''.3427 \sin \varsigma + 0''\ 0041 \sin 2\Omega - 0''.0252 \sin 2\odot \\
&+ 0''.0024 \sin (82^\circ + \odot) + 0''.0002 \sin (2\odot - \Omega) \\
&- 0''.0001 \sin (3\odot - 281^\circ.2) - .00004 \sin 2(\odot - \Omega) \\
&+ 0.0001 \sin 2(\odot - T') - .00405 \sin 2\,\mathfrak{D} + .00133 \sin (\mathfrak{D} - T')] \, n \cos \alpha \\
&+ [9''.2240 \cos \varsigma - 0''.0895 \cos 2\Omega + 0''.5506 \cos 2\odot \\
&+ 0''.0092 \cos (282^\circ.2 + \odot) - 0''.0067 \cos (2\odot - \Omega) \\
&+ 0.0027 \cos (3\odot - 281^\circ.2) + 0''.0023 \sin T' + 0.0885 \cos 2\,\mathfrak{D} \\
&+ 0.0181 \cos (2\,\mathfrak{D} - \Omega)] \sin \alpha \\
&- 20''.4451 \cos \omega \cos \odot (\tan \omega \cos \delta - \sin \alpha \sin \delta) \\
&- 20''.4451 \sin \odot \cos \alpha \sin \delta \\
&+ \tau\mu'
\end{aligned}$$

Put

$$\begin{aligned}
A = \tau &- 0''.3427 \sin \varsigma + 0''.0041 \sin 2\varsigma - 0''.0252 \sin 2\odot \\
&+ 0''.0024 \sin (82^\circ + \odot) + 0''.0002 \sin (2\odot - \Omega) \\
&- 0.0001 \sin (3\odot - 281^\circ.2) - .00004 \sin 2(\odot - \varsigma) \\
&+ 0.0001 \sin 2(\odot - T') - .00405 \sin 2\,\mathfrak{D} + .00134 \sin (\mathfrak{D} - T') \\
B = &- 9''.2240 \cos \varsigma + 0''.0895 \cos 2\varsigma - 0''.5506 \cos 2\odot \\
&- 0.0092 \cos (281^\circ.2 + \odot) + 0\ 0067 \cos (2\odot - \varsigma) \\
&- 0.0027 \cos (3\odot - 281^\circ.2) - 0.0023 \sin T' - 0.0885 \cos 2\,\mathfrak{D} \\
&- .0181 \cos (2\,\mathfrak{D} - \Omega) \\
C = &- 20''.4451 \cos \odot \cos \omega \\
D = &- 20''.4451 \sin \odot \\
E = &- 0.0364 \sin \varsigma + 0.0039 \sin 2\varsigma - 0.0028 \sin 2\odot \\
&+ 0''.0230 \sin (82^\circ + \odot) + 0''.0030 \sin (2\odot - \varsigma) - \ldots .
\end{aligned}$$

These quantities depend on the date and are independent of the star's place; they are computed and tabulated for each Washington mean midnight on pages 281-292, under the name of Besselian Star Numbers.

We also put

$$\begin{aligned} a &= m + n \sin \alpha \tan \delta \\ &= 46''.0907 + 20''.0410 \sin \alpha \tan \delta \\ &= 3^s.07267 + 1^s.33606 \sin \alpha \tan \delta \\ b &= {}_1{}^1{}_5 \cos \alpha \tan \delta \\ c &= {}_1{}^1{}_5 \cos \alpha \sec \delta \\ d &= {}_1{}^1{}_5 \sin \alpha \sec \delta \end{aligned}$$

and

$$\begin{aligned} a' &= n \cos \alpha = 20''.0410 \cos \alpha \\ b' &= -\sin \alpha \\ c' &= \tan \omega \cos \delta - \sin \alpha \sin \delta \\ d' &= \cos \alpha \sin \delta \end{aligned}$$

all of which depend on the star's place and are sometimes given in the star catalogues.

Then we have

$$\alpha' = \alpha + \mathrm{A}a + \mathrm{B}b + \mathrm{C}c + \mathrm{D}d + \mathrm{E} + \tau\mu \qquad \text{(in time)}$$
$$\delta' = \delta + \mathrm{A}a' + \mathrm{B}b' + \mathrm{C}c' + \mathrm{D}d' + \tau\mu' \qquad \text{(in arc)}$$

Another transformation which is sometimes more convenient than the above is made as follows:

Put

$$f = 46''.0907\mathrm{A} + \mathrm{E} = 3^s.07267\mathrm{A} + {}_1{}^1{}_5\mathrm{E} \qquad \text{(in time)}$$

$g \sin \mathrm{G} = \mathrm{B}$ $\quad h \sin \mathrm{H} = \mathrm{C}$ $\quad$ and $\quad i = \mathrm{C} \tan \omega$

$g \cos \mathrm{G} = 20''.0410\mathrm{A}$ $\quad h \cos \mathrm{H} = \mathrm{D}$

Then we shall have

$$\begin{aligned} \alpha' &= \alpha + f + {}_1{}^1{}_5 g \cos \mathrm{G} \sin \alpha \tan \delta + {}_1{}^1{}_5 g \sin \mathrm{G} \cos \alpha \tan \delta \\ &\quad + {}_1{}^1{}_5 h \sin \mathrm{H} \cos \alpha \sec \delta + {}_1{}^1{}_5 h \cos \mathrm{H} \sin \alpha \sec \delta + \tau\mu \\ &= \alpha + f + {}_1{}^1{}_5 g \sin (\mathrm{G} + \alpha) \tan \delta + {}_1{}^1{}_5 \sin (\mathrm{H} + \alpha) \sec \delta \\ &\quad + \tau\mu \qquad \text{(in time)} \end{aligned}$$

and

$$\begin{aligned} \delta' &= \delta + g \cos \mathrm{G} \cos \alpha - g \sin \mathrm{G} \sin \alpha - h \sin \mathrm{H} \sin \alpha \sin \delta \\ &\quad + h \cos \mathrm{H} \cos \alpha \sin \delta + i \cos \delta + \tau\mu' \\ &= \delta + g \cos (\mathrm{G} + \alpha) + h \cos (\mathrm{H} + \alpha) \sin \delta + i \cos \delta \\ &\quad + \tau\mu' \qquad \text{(in arc)} \end{aligned}$$

The quantities f, G, H, g, h, and i are called the Independent Star Numbers and are computed for every Washington mean midnight—see pages 285-292. Since the coefficients of sin ☊, sin 2☉ etc. in the terms of A, B, C and D remain sensibly constant for a long period, the values of the several terms can be tabulated with

Ω, $2\odot$, 2Ω, $82° + \odot$, etc., as arguments and thus the computation of the Besselian Numbers is greatly facilitated.

The preceding formulæ are accurate for all stars except those very near the pole. For the latter all appreciable terms must be included and especially those involving the tangent and secant of the declination. It now remains to determine the value of τ or the date of the beginning of the fictitious year or when the Sun's *mean* longitude is 280°. This date does not correspond to the beginning of the tropical year on the meridian of Greenwich. It is evident that the meridian on which this fictitious year begins, must vary from year to year and since the Sun's mean longitude is always equal to his mean R. A., the sidereal time at this meridian when the fictitious year begins must be $18^h\ 40^m = 280°$. Now according to Bessel, the Sun's *mean* longitude at mean noon at Paris on 1800, Jan. 0, was 279° 54′ 1″.36 which quantity is usually denoted by E. The student must be careful not to confound this number with the quantity E in the preceding formulæ; he must also remember that by Jan. $0^d.0$ is meant Dec. 31, noon, or Dec. $31^d.0$. The Sun's *sidereal* motion in 365.25 days is

$$360° - 22''.617656.$$

This is estimated from a *fixed* point of the ecliptic, but the *mean* longitude is referred to the *moving equinox*, and it therefore follows that the mean motion is equal to the sidereal plus the general precession in the same time. Bessel's general precession is 50″.2235, hence the mean motion in 365.25 days (neglecting the secular variation)

$$= 360° - 22''.617656 + 50''.2235$$
$$= 360° + 27''.605844$$

Therefore the mean daily motion = 59′ 8″.3302 and the mean motion in 365 days = mean motion in 365.25 days less one fourth of the mean daily motion or 14′ 47″.083. Now it is plain that the value of E for any year, say $1800 + t$, is found by adding the motion in 365 days for each common year and the motion in 366 days for each leap year, so that if r denote the remainder after dividing t by 4, we shall have for the date $1800 + t$, Jan. 0, Paris mean time

$$\mathrm{E} = 279° 54' 1''.36 + 27''.6058\ t - (14' 47''.083)\ r$$

and if we denote by τ, the mean time interval from the beginning of the fictitious year to Jan. 0 of any year, we must have

$$\tau = \frac{E - 280^\circ}{\text{mean daily motion}} = -0.10107 + 0.00777995\,t - \tfrac{1}{2}\tau$$

expressed in mean solar days.

Suppose, for example, we require the date of the beginning of the fictitious year for 1890 for Washington, D. C. By the preceding we have for 1890, Jan. 0, Paris M. T.,

$$E = 279^\circ\ 54'\ 1''.36 + 27''.6058 \times 90 - (14'\ 47''.083) \times 2$$
$$= 280^\circ\ 5'\ 51''.72$$

which shows that the Sun attained the mean longitude of 280° some time *before* Jan. 0; or the meridian on which the fictitious year began is *east* of Paris. Then we have

$$\tau = -0.10107 + .70020 - .5 = +0.09912d$$
$$\text{Long. of Paris} = 5^h\ 17^m\ 33^s = 0.22052$$
$$\tau = 0.31964 \text{ or } 0^d.320$$

that is, 0.320 days before Jan. 0 or 1889, Dec. $30^d.680 = 1890$, Jan. $0^d.0 - 0^d.320$ Washington mean time.

We will now close this paper with the following example:

Find the Besselian and Independent star numbers for July 1st, 1890, Washington mean midnight—that is for 1890, July $1^d.5$. The interval from 1889, Dec. $30^d.680$ to 1890, July $1^d.5$, is 182.820 days = 0.5005 years = τ. On page 278 of the Ephemeris we find for July 1.5, $\odot = 82^\circ\ 54'\ 15''$; on page 112 we find $\odot = 100^\circ\ 13'\ 28''$ and on page 274, $\mathfrak{D} = 274^\circ\ 49'$. The value of T′ or the longitude of the Moon's perigee is not given in the Ephemeris and indeed the terms involving it are almost inappreciable, but if it is deemed necessary to include them in the values of A and B, we will here indicate how it may be found with sufficient accuracy for our purpose.

The longitude of the perigee of the Moon or of the perihelion of a planet is measured on the plane of the orbit of the Moon or planet and not on the ecliptic, and is equal to the distance of the Moon or planet from the node plus the longitude of the node. For this reason the perigee or perihelion is not regarded as having a latitude, while the Moon or planet when referred to the ecliptic, has both longitude and latitude. Now when the Moon is in perigee which occurs on July 3^d, $2^h.4$ Greenwich M. T., or July $2^d\ 21^h.264$ Washington M. T., (see page 121) the Moon's longitnde will also be the longitude of perigee *referred to the ecliptic*. From page 274 we then find for this date

$$\mathfrak{D}\text{'s long.} = 295^\circ\ 40'\ 19''$$
$$\mathfrak{D}\text{'s lat.} = -\ 2^\circ\ 38'\ 44''$$

approximately. If we now deduct the mean longitude of the node at the same time or $82^\circ\ 50' = \Omega$, we shall have $212^\circ\ 50'\ 19''$ and $-\ 2^\circ\ 38'\ 44''$ for the two sides of a right angled spherical triangle to find the third side or hypotenuse which is the distance from the perigee to the node. Denoting this distance by $\varkappa$, the $\mathfrak{D}$'s longitude and latitude by λ and β, respectively, we have

$$\cos \varkappa = \cos (\lambda - \Omega) \cos \beta$$

from which we find	$\varkappa = 212^\circ\ 56'$
to which add	$\Omega = 82\ \ 50$
and we have	$T' = 295^\circ\ 46'$

The perigee has a mean daily motion of about $+\ 6'\ 40''$, and therefore deducting the motion in $1^d\ 9^h.264$ we shall have for

July $1^d\ 12^h$ Washington M. T., $T' = 295^\circ\ 43'.4$

which is of course only an approximate value but quite near enough for our purpose. We will now resume the computation of A, B., etc.

BESSELIAN STAR NUMBERS.

log .3427 = 9.53491	.0041 = 7.61278	.0252 = 8.40140
sin Ω = 9.99666	sin 2Ω = 9.38946	sin 2$\odot$ = 9.54330n
.340070 = 9.53157	.001005 = 7.00224	− .00880 = 7.94470n
.0024 = 7.38021	.0002 = 6.30103	.0001 = 6.00000
sin (82 + $\odot$) = 8.58932n	sin (2$\odot$ − Ω) = 9.94775	sin (3$\odot$ − 281°.2) = 9.52292
− .00093 = 5.96953n	.000177 = 6.24878	.000033 = 5.52292
0.0001 = 6.00000	.00405 = 7.60260	.00134 = 7.12710
sin 2($\odot$ − π') = 9.42690	sin 2 $\mathfrak{D}$ = 9.22361n	sin ($\mathfrak{D}$ − T') = 9.55235n
.000027 = 5.42690	− .00067 = 6.82621n	− .000478 = 6.67945n

A = .50053 − .34007 + .001005 + .00880 − .000093 + .000177 − .000033 + .000027 + .00067 − .000478 = + 0.17055 and log. A = 9.23184.

log 9.2240 = 0.96492	.0898 = 8.95182	.5506 = 9.74084
cos Ω = 9.09177	cos 2Ω = 9.98654n	cos 2$\odot$ = 9.97173n
1.13945 = 0.05669	− .08677 = 8.93836n	− .51590 = 9.71257n
.0092 = 7.96379	.0067 = 7.82607	.0027 = 7.43136
cos(281°.2 + $\odot$) = 9.96890	cos (2$\odot$ − $\mathfrak{R}$) = 9.66505n	cos(3$\odot$ − 281°.2) = 9.97443
.00856 = 7.93269	− .00310 = 7.49112n	.00255 = 7.40579
.0023 = 7.36173	.0885 = 8.94694	.0181 = 8.25768
sin T' = 9.95470n	cos 2 $\mathfrak{D}$ = 9.99383n	cos(2 $\mathfrak{D}$ − Ω = 9.45927n
− .00207 = 7.31643n	− .08720 = 8.94077n	− .00521 = 7.71695n

$B = -1.13945 - .08677 + .51590 - .008564 - .003098 - .002545 + .002072$
$+ 0.0872 + 0.00521 = -0.6308, \qquad \log B = 9.79962n.$

$-20''.4451 = 1.31059n$	$-20''.4451 = 1.31059n$
$\cos \odot = 9.24921n$	$\sin \odot = 9.99305$
$\cos \omega = 9.96255$	
$\log C = 0.52235$	$\log D = 1.30364n$
	and $E = -0''.275$

These coefficients differ slightly from those in the Ephemeris; this is due partly to the fact that different values of Δl and $\Delta\omega$, as well as of m and n, are here employed and also to the omission of several very small terms.

THE INDEPENDENT STAR NUMBERS.

$46''.0907 = 1.66362$	$20''.0410 = 1.30192$
$A = 9.23184$	$A = 9.23184$
$7''.861 = 0.89546$	$g \cos G = 0.53376$
$.15 = 1.17609$	$g \sin G = 9.79962n$
$0^s.5241 = 9.71937$	$\tan G = 9.26586n$
	$G = 349^\circ\ 33'$
$1.15\ E = -0.014$	$\sin G = 9.25858n$
$0.510 = f$ (in time)	$\log g = 0.54104$
$h \sin H = 0.52235$	$\log C = 0.52235$
$h \cos H = 1.30364n$	$\tan \omega = 9.63732$
$\tan H = 9.21871n$	$\log i = 0.15967$
$H = 170^\circ\ 36'\ 16''$	$i = 1''.45$
$\sin H = 9.21309$	
$\log h = 1.30926$	

These also differ slightly from the values given in the Ephemeris for the reasons already given.

Examples showing the use of these numbers are given in the Explanation of the Ephemeris and therefore need not be repeated here. When the reader shall have gone through this long and tedious investigation, he will doubtless come to the conclusion that the so-called fixed stars are by no means what they are represented to be. The difficulty, however, is not due to any motion in the stars themselves but to the fact that the plane and point of reference are constantly in motion, thus necessitaing the application of three of the astronomical corrections, viz, precession, nutation and aberration.

A number of new problems and acknowledgement of those solved will be given in the next number.

(TO BE CONTINNED.)

THE PLANETS AND CONSTELLATIONS FOR AUGUST, 1896.

Mercury begins the month behind the Sun, having passed superior conjunction July 31, and will not be in favorable position for observation during the month. Mercury will be in conjunction with Jupiter, Aug. 4, at midnight, Central standard time, and with Venus, Aug. 8, at 8^h A. M.

THE CONSTELLATIONS AT 9^h P. M. AUGUST 1, 1896.

Venus is also behind the Sun and will not be in good position during August. Venus and Jupiter will be in conjunction Aug. 2, at 5^h P. M. If we could see Venus at this time her phase would be full and round like that of Jupiter. The two planets will then be less than 1° apart.

Mars rises before midnight and is all the time getting into better position. He will be at quadrature, 90° west from the Sun, at midnight, Aug. 31. The phase of Mars this month is as small as it ever is, only 0.85 of the disk being illuminated. The apparent diameter of the planet increases from 8.5″ to 10.0″ during August so that the principal surface markings will be more readily seen. The moon passes about 6° to the north of Mars, Aug. 2, and again Aug. 31. The observer will easily find Mars, on the morning of Aug. 1, in the (otherwise) vacant space southwest of the Pleiades. Directly east from Mars is the group of the Hyades in Taurus, in which the first magnitude star Aldebaran has nearly the same color and brightness as Mars. During the month Mars will move northeastward in the sky, between the Pleiades and Hyades, and on the 31st will stand almost due north of Aldebaran.

Jupiter will be in conjunction with the Sun Aug. 11 and so will be invisible during the month.

Saturn will be at quadrature, 90° east from the Sun, Aug. 4. His situation is becoming unfavorable and good observations can be obtained only in the early evening twilight. Saturn may be seen with the naked eye at 9^h P. M. in Libra toward the southwest.

Uranus will be at quadrature, 90° east from the Sun, Aug. 12, and because of its low altitude is practically out of view for this year. It may be found low in the southwest in Libra, in R. A. 15^h 12^m and Decl. — 17° 36′.

Neptune may be seen in the morning at the same time with Mars. This planet is about 30° east of Mars in the horn of Taurus, between 3° and 4° west of the star ζ Tauri. It appears a star of about the eighth magnitude, and only a large telescope will show its disk.

Occultations Visible at Washington.

Date 1896.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle f'm N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N pt. °	Duration. h m
Aug. 2	*g* Pleiadum	6.5	11 46	118	12 22	203	0 36
2	19 Tauri	5.0	11 52	80	12 46	239	0 54
2	21 Tauri	7.0	12 11	73	13 6	225	0 55
2	20 Tauri	5.0	12 11	118	12 48	201	0 37
2	22 Tauri	7.0	12 14	81	13 8	237	0 54
16	τ Scorpii	3.2	8 30	124	9 37	242	1 7
21	31 Capricorni	6.7	6 41	55	7 53	263	1 12
21	ι Capricorni	4.4	9 51	13	10 51	284	1 0
22	e^2 Aquarii	5.6	10 24	49	11 50	237	1 26
22	B. A. C. 7740	7 0	12 19	14	13 26	266	1 7
23	B. A. C. 8017	6.1	15 50	57	17 0	212	1 10
24*	13 Piscium	6.4	6 32	7	7 3	301	0 31
24†	14 Piscium	5.9	7 16	110	7 57	192	0 41
29	7 Tauri	6.0	15 58	61	17 29	253	1 31

* Whole occultation below the horizon at Washington. † Immersion below the horizon at Washington.

A Partial Eclipse of the Moon, Aug. 22, 1896.—This will be visible throughout the United States, beginning at 10^h 6^m P. M. and ending at 3^h 48^m A. M. Central Standard Time. About three quarters of the diameter of the Moon's disk will be immersed in the shadow at the time of greatest obscuration.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, Aug. 22, $19^h\ 32^m\ 3^s.4$.

Sun's right ascension	10^h	10^m	$44^s.30$	Hourly motion		$9^s.20$		
Moon's right ascension	22	10	44 .30	Hourly motion		112	.81	
Sun's declination	11°	15′	37″.3N	Hourly motion		0′	51″.2S	
Moon's declination	10	38	44 .8S	Hourly motion		13	29	.8N
Sun's equa. hor. parallax			8 .7	Sun's true semi-di.		15	49	.6
Moon's equa. hor. parallax		55	4 .2	Moon's true semi-di.		14	59	.6

TIMES OF PHASES.

	Greenwich Time.			Central Standard Time.			
		h	m		h	m	
Moon enters penumbra	Aug. 22	16	6.7	Aug. 22	10	6.7	P. M.
Moon enters shadow		17	24 5		11	24.5	"
Middle of eclipse		18	57.5	Aug. 23	12	57.5	A. M.
Moon leaves shadow		20	30.4		2	30.4	"
Moon leaves penumbra		21	47.9		3	47.9	"

Magnitude of eclipse = 0.735 (Moon's diameter = 1.0)

The shadow will pass across the southern portion of the Moon's disk, striking first near the east point and passing off between the south and west points of the disk.

VARIABLE STARS.

Dr. Chandler's "Third Catalogue of Variable Stars" has just appeared in *Astronomical Journal*, No. 379, dated July 7. Its publication will be hailed with delight by all astronomers, especially those engaged in this fascinating branch of work.

The three years which have elapsed since the "Second Catalogue" appeared have been years of great activity in this direction. As a result the number of known variables now amounts to 393, a gain of 50 per cent over the previous list. This increase has been chiefly in the southern hemisphere. In the Second Catalogue there were 154 stars in north declination, or 59 per cent of the whole. In the Third however, there are 194 northern stars, or only 49 per cent of the total number. The increase in northern stars has been only 40, while 93 new variables have been discovered south of the equator. There are three principal sources of this increase in southern stars. The examination of the Harvard photographic plates has resulted in the discovery of 60 new variables, a large proportion of which are in the southern hemisphere. Professor Roberts, of Lovedale, South Africa, has discovered 20, mostly short period stars. The variability of many stars of the Cordoba Durchmusterung has been suspected by Dr. Thome, and 9 of these have been confirmed by other observers.

A large proportion of the discoveries in the northern hemisphere have arisen from the spectroscopic work done at the Harvard College, and also by Espin. These discoveries have been confirmed by numerous observers, many by Dr. Chandler himself, some by Hartwig, 21 by H. M. Parkhurst, and 31 by Yendell.

One result of the large number of new variables is the fact that the interval of time by which the minimum precedes the maximum is only known in 142 cases, as against 115 in the previous list; an increase of only 23 per cent, not at all in proportion to the number of new objects. It will therefore be seen that the most useful field for work consists in observing the minima of known variables, a fact which the author emphasized in the Second Catalogue, but which applies with still greater force at the present time.

A change in the author's plan is seen from the admission into the catalogue of the variables discovered on the Harvard photographs, and confirmed, not by strictly independent observation, but by independent examination of the plates by Professor Pickering. The reason for this change was given by Dr. Chandler in *Astronomical Journal*, No. 347.

The star T Draconis, was entered in the "Revised Supplement to the Second Catalogue" with the number 6446. The R. A. has since been found to be about 30 seconds greater than first announced by Espin, and in consequence the number (one-tenth the R. A. for 1900, expressed in seconds) has been changed to 6449. It is a question whether this was an intentional change or an oversight.

At the close of the catalogue, together with a list of suspected but unconfirmed variables in the Cordoba Durchmusterung, there is given a useful and suggestive list of "Missing Durchmusterung Stars." They are 26 in number, with D. M. magnitudes from 9.2 to 9.5.

Altogether the new catalogue is an incentive to greater activity in this department, and as the accumulated observations of the past three years have been carefully sifted, the observer is insured that by its guidance his work may be of greater usefulness.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

Aug.	18	22
	23	22
	28	21

ALGOL.

Aug.	7	22
	10	19
	13	16
	30	20

λ TAURI.

Aug.	2	20
	6	19

δ LIBRÆ.

Aug.	3	16
	10	16
	17	16
	24	15
	31	15

U CORONÆ.

Aug.	3	13
	27	17

U OPHIUCHI.

Aug.	1	19
	2	15
	6	20
	7	16
	12	17
	13	13
	17	18
	18	14
	22	18
	23	15
	27	19
	28	15

Z HERCULIS.

Duner has lately shown that this star cannot be observed in the U. S. till 1898.

W DELPHINI.

Aug.	4	1
	8	21
	13	16
	18	12
	23	7
	28	2

U CEPHEI.

1896.

	d	h
Sept.	2	21
	7	21
	12	20
	17	20
	22	20
	27	19

ALGOL.

Sept.	2	17
	5	14
	19	22
	22	19
	25	16
	28	13

R CANIS MAJ.

1896.

	d	h
Sept.	6	19
	7	22
	14	18
	15	21
	23	20
	24	23

Y BOOTIS.

(See note.)

Aug.	7	12
	12	17
	20	13
Sept.	2	13
	15	14
	28	14

U CORONÆ.

1896.

	d	h
Sept.	3	15
	10	12

U OPHIUCHI.

Sept.	2	16
	3	12
	7	17
	8	13
	13	14
	18	15
	23	15
	28	16

W DELPHINI.

1896.

	d	h
Sept.	1	22
	6	17
	11	12
	16	8
	21	3
	25	22
	30	18

Maxima and Minima of Long Period Variables.

MAXIMA.

1896 September.

Date.	No.	Star.
2	114	S Ceti
5	8290	R Pegasi
8	5889	U Herculis
9	2976	V Cancri
11	6062	RR Scorpii
15	2857	U Puppis
16	2691	T Canis Min.
16	4511	T Ursæ Maj.
17	8230	S Aquarii
19	6905	R Sagittarii
29	7609	T Cephei
30	3128	R Pyxidis

MINIMA.

1896 September.

Date.	No.	Star.
2	5758	X Herculis
3	7120	χ Cygni
5	6849	R Aquilæ
7	5237	R Bootis
8	5583	X Libræ
10	845	R Ceti
10	7560	R Vulpeculæ
12	7448	W Aquarii
14	7468	T Aquarii
15	7659	T Capricorni
23	4557	S Ursæ Maj.
24	4492	Y Virginis
26	6921	S Sagittarii

MAXIMA.

1896 October

Date	No.	Star.
1	7045	R Cygni
4	5887	V Ophiuchi
5	5955	R Draconis
7	432	S Cassiopeæ
8	243	U Cassiopeæ
8	2625	V Geminorum
8	5677	R Serpentis
11	1222	R Persei
12	7907	U Aquarii
12	2266	V Monocerotis
13	7234	R Capricorni
13	2080	R Columbæ

MAXIMA CONT.

1896 October.

Date	No.	Star.
16	7242	S Aquilæ
16	8600	R Cassiopeæ
16	7299	U Cygni
17	1113	U Arietis
21	8597	V Ceti
21	494	R Sculptoris
24	5511	RS Libræ
24	1574	W Tauræ
25	3881	V Hydræ
27	782	R Arietis
30	107	T Cassiopeæ
31	5928	T Ophiuchi

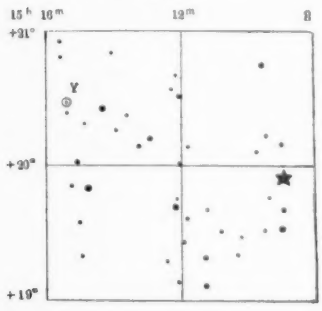
MINIMA.

1896 October.

Date	No.	Star.
4	7999	X Aquarii
7	5950	W Herculis
12	4826	R Hydræ
14	7085	RT Cygni
20	4521	R Virginis
22	3825	RUrsæMajoris
24	2100	U Orionis
24	466	U Piscium
28	5494	S Libræ

From Hartwig's ephemeris in the *Vierteljahrsschrift* except that for W Delphini I have used Pickering's ephemeris in the March *Astrophysical Journal*, and for Y Bootis, H. M. Parkhurst's elements.

The Algol Type Variable 5144 Y Bootis.—The ephemeris of the above variable for August and September is given in the proper place in this number. The star's place is as follows:



R. A., $14^h\ 15^m\ 16^s$ Dec. $+ 20°\ 28'.2$ (1855)
$14\ 17\ 22$ $20\ 15\ .8$ (1900)

The star is D. M. $+ 20°.2970$. Its fluctuations were noticed by Mr. Henry M. Parkhurst in 1886. In 1894 he published an account of its variations and assigned a period of 2.6052 days. The variation was confirmed by Yendell in 1893. The change lasts about four hours, and is from 8 0 to 8.6 magnitude. Being in the vicinity of Arcturus it is easy to find. The accompanying chart will aid in its identification, Arcturus being shown at $15^h\ 9^m$, $+ 20°\ 7'$.

J. A. PARKHURST.

COMET NOTES.

Definitive Elements of the Orbit of Comet 1890 IV.—The following elements by A. Venturi, of Palermo, are given in *Astronomische Nachrichten* No. 3351. They depend upon a great number of observations and represent the normal places almost exactly. The orbit differs very little from a parabola but is apparently a very long ellipse. The period according to these elements would be about 11,000 years.

$T = 1890$ August 6.91990 Berlin mean time.
$\omega = 331° 15' 3''.7$
$\Omega = 85 22 5 .1$ } 1890.0.
$i = 154 18 26 .7.$
$e = 0.995872.$
$\log g = 0.311053.$

Ephemeris of Comet *b* 1896 (Swift).—The following is a part of an ephemeris by Dr. R. Schorr in *Astronomische Nachrichten*, No. 3356:

		App. R. A.			App. Decl.			log r	log Δ	Brightness
		h	m	s	°	′	″			
Aug.	1	19	13	55	+ 54	46	0			
	2		12	54		54	14.2	0.3136	0.1893	0.011
	3		11	58		53	42.3			
	4		11	5		53	10.4			
	5		10	16		52	38.4			
	6		9	30		52	6.4	0.3255	0.2008	0.010
	7		8	48		51	34.3			
	8		8	9		51	2.0			
	9		7	33		50	29.7			
	10		7	1		49	57.3	0.3371	0.2129	0.009
	11		6	31		49	25.0			
	12		6	4		48	52.7			
	13		5	40		48	20.6			
	14		5	19		47	48.5	0.3482	0.2254	0.008
	15		5	1		47	16.5			
	16		4	45		46	44.6			
	17		4	31		46	12.8			
	18	19	4	20	+ 45	41	1	0.3590	0.2382	0.007

Ephemeris of Comet *c* 1896 = Comet 1889 V.—The following is a part of Dr. Bauschinger's ephemeris in *Astronomische Nachrichten*, No. 3361:

		App. R A.			App. Decl.			log Δ	Brightness.
		h	m	s	°	′	″		
Aug.	1	22	38	22.8	− 18	29	32		
	2		38	5.6		31	14		
	3		37	46.8		32	58		
	4		37	26.4		34	44	0.0529	1.59
	5		37	4.5		36	30		
	6		36	41.0		38	17		
	7		36	16.1		40	4		
	8		35	49.8		41	51	0.0436	1.68
	9		35	22.0		43	38		
	10		34	53.0		45	23		
	11		34	22.7		47	6		
	12		33	51.2		48	48	0.0353	1.76
	13		33	18.5		50	27		
	14		32	44.7		52	2		
	15		32	9.9		53	34		
	16	22	31	34.1	− 18	55	2	0.0284	1.84

GENERAL NOTES.

For information concerning the business matters of this publication reference should be made to the last page of each number.

Professor C. A. Young calls attention to an error in statement at the bottom of page 412, April number, where the writers quote him as saying along with Proctor and Flammarion, "that Galileo's great perplexity" (about the peculiar behavior of the appendages he had discovered attached to Saturn) "led him to abandon all further observations." Professor Young says: "I do not think I ever made such a statement, for I have long known better; and I certainly have not asserted anything of the kind in either of my three astronomical text books. I simply say nothing about later observations by Galileo (because they added no new knowledge), but proceed to mention that the problem was first solved by Huyghens nearly fifty years later, as was the fact."

We called the authors' attention to this matter some time ago, in the hope that they themselves would make the correction. In justice to Professor Young they ought to have done it promptly.

Telescope-Making in the United States During Sixty Years.—In connection with the article published by Professor Young in the North American Review of February last, under the title, The Newest Telescope, a foot-note to the second page is as follows:

"It is difficult to realize the progress of the last sixty years in the matter of telescope-making. In 1836 the two most powerful refracting telescopes in the world were the 9½-inch instrument at Dorpat and the 11-inch at Munich. In the United States the largest instrument was the 5-inch Dolland telescope of Yale college, High School. Before 1850 several other German instruments were imported, the most notable being the 11-inch telescope at Cincinnati, the 9½-inch at Washington, and the 15-inch at Cambridge, which, with its twin at Pulkowa (dating from 1839) for many years shared the honor of being the largest in existence. It was in 1846 that Alvan Clark, Sr., made his first telescope, and since 1850, very few telescopes of any importance have been imported, while a number of Clark's lenses have gone abroad. Fitz and Spencer also have made a number of large telescopes between 1850 and 1870, and at present, Brashear, of Pittsburg, is vigorously competing with the Clarks themselves in size and excellence of his object-glasses."

Dr. Morrison's Articles.—Amatuers are pleased with Dr. Morrison's very valuable articles in relation to the structure of the American Ephemeris and Nautical Almanac. At different times during the last five years, we have been repeatedly asked to furnish just this information, and we have considerd ourselves extremely fortunate in securing one so able and so willing to do this useful piece of work. That Dr. Morrison fully understands what he is writing about is without question, for he has been, for many years, in charge of this kind of work at the Nautical Almanac office in Washington under Prof. Simon Newcombe as Superintendent. It is therefore a matter of very great interest that the student and amateur can have the details of all this practical work in the Nautical Almanac fully explained and illustrated by examples to show as clearly as possible how useful results are obtained and the mathematical principles involved in them.

We are aware that these eight or nine pages of Dr. Morrison's writing, from

time to time, are too hard reading for many of our subscribers, and, as they sometimes say to us, they do not see how we can call such popular astronomy. Indeed, we can not call these articles in the broadest sense, popular matter, for they freely use some branches of higher mathematics. On this account, as we have before said, we have added eight pages to every number of this publication, latterly, giving 56 pages instead of 48, that we might furnish for the sake of the amateurs that for which they have so kindly asked, and that which many of them must have as we well know if they are able to go on with their studies in the elements of practical astronomy, as they should do.

Early Observations of the Zodiacal Light.—Mr. W. T. Lynn, in July *Observatory*, brings to attention some points relating to early observations of the Zodiacal light that we had not before seen:—He says: "The first person I believe, who gave what is undoubtedly a real description of the Zodiacal Light was Joshua Childrey, in a small book published in 1660 under the somewhat fanciful title of 'Brittannica Baconica.' This gives a very brief sketch of the natural history of England and Wales under the different counties and a still shorter of that of Scotland. The whole consists of no more than 184 pages, and in the last two, after describing (which also he seems to have been the first to notice) the black space in the Milky Way between Cygnus and Cepheus, which has been compared to the so-called coal-sack near the Southern Cross he writes thus:—

'In February and for a little time before, and a little after, that month (as I have observed several years together), when the Twilight hath almost deserted the *Horizon*, you may see a plainly discernible way of the Twilight striking up toward the *Pleiades* or seven Stars, and seeming almost to touch them. It is to be observed almost any clear night, but it is best *illuc nocte*. There is no such way to be observed at any other time of the year (that I can perceive) nor any other way at that time to be perceived darting up elsewhere. And I believe it hath been and will be constantly visible at that time of the year. But what the cause of it in nature should be, I can not yet imagine, but leave it to further enquiry.'

'No mention, it may be remarked, is made of these observations of the black spot near Cygnus, or of the Zodiacal Light, in the account in Childrey, contained in the tenth volume of the Dictionary of National Biography. And I can not but express my regret that both in the title of his book, and in quotations generally, the translators of Arago's Astronomie Populaire have re-translated from the French instead of referring to the original English."

Stars Having Peculiar Spectra.—A list of stars having peculiar spectra is given in the annexed table. They were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial photographs. The number of stars of the third type is so large, now amounting to several thousands, that it has not been thought worth while to announce them, but to reserve them for a full list of stars having peculiar spectra to be published in a volume of the Annals. In the following table, the designation of the star in the Durchmusterung catalogues is given in the first column when it occurs in that work. The approximate right ascension and declination for 1900 are given in the next two columns, followed by the Durchmusterung magnitude. The fifth column gives the character of the spectrum, followed by additional remarks when required.

Designation.	R. A. 1900.	Dec. 1900.	DM. Magn	Description.
°	h m	° ′		
— 81 099	5 17.6	— 8 45	7.0	Peculiar.
.....	7 38.3	— 70 7	.....	Peculiar.
.....	10 52.0	— 59 51	.....	Peculiar. Resembles η Carinæ.
— 37 7905	12 24.0	— 37 42	8.8	Type IV. [— 0° 30′.
— 34 11675	17 18.5	— 34 6	10.	Type V. Gal. long. 320° 56′, lat.
— 39 12196	17 58.2	— 39 20	9 0	Type IV. [— 1° 34′.
.....	18 17.5	— 13 46	.....	Type V. Gal. long. 345° 14′, lat.
.....	18 22 2	— 16 53	.....	Type V. Gal. long. 343° 2′, lat.
— 25 13170	18 23.2	— 25 19	7.6	Hβ bright. [— 4° 04′.
— 38 12843	18 23.4	— 38 29	9.5	Type IV.
— 31 15954	18 40.0	— 31 28	9.2	Peculiar.
— 29 15574	18 52.4	— 29 38	8.9	Peculiar.
— 40 13448	19 37.1	— 40 40	9.0	Peculiar. Resembles Carinæ.
— 18 5480	19 40.6	— 18 24	9.1	Type IV.
+ 85 332	19 43.8	+ 85 9	9.2	Type IV. [lat. — 12° 09′.
.....	20 15 6	+ 16 25	.....	Gaseous Nebula. Gal.long.26°13′
— 12 5755	20 26.2	— 12 13	9 2	Type IV.
+ 5 5223	23 44.0	+ 5 50	8.7	Type IV.

Of the seven stars whose spectra are here announced as of Type IV, the first, second and seventh are normal. The spectra of the others contain rays of much shorter wave-length than ordinary fourth type stars. The spectra of two faint objects announced as peculiar in the Astron. Nach. Vol. 135, p. 195 have been shown by recent and better photographs to belong to a different class from that there given. One of these whose approximate position for 1900 is R. A. $17^h\,38^m.2$, Dec. — 46° 3′ announced as a stellar object having the spectrum of a gaseous nebula proves to have a faint continuous spectrum in which the hydrogen lines Hβ, Hγ, Hδ, Hε, and Hζ are bright, and the bright line at 5007 is absent, so that it more nearly rerembles the spectrum of η Carinæ. The second object, — 33° 13537, R. A. $18^h\,39^m.3$, Dec. — 33° 27′ (1900), announced as of the fifth type proves to have the spectrum of a gaseous nebula.—*Harvard College Observatory Circular No. 9.*

EDWARD C. PICKERING.

July 9, 1896.

Photographic Doublet for Japan made by J. A. Brashear, of Allegheny, was shipped for that country about the middle of June, and it was expected to reach its destination about the first of July. It is to be used by Japan astronomers during the total eclipse of the Sun on the 8th of August next.

Its clear aperture is 8 inches and its focal length is 48 inches. Mr. Brashear has just finished the 5-inch objective for the new alt-azimuth optical equipment for the Observatory of the University of Pennsylvania, the six collimating lenses having been shipped to Messrs. Warner & Swasey. He has also one of the discs for the 12″ for the Illinois State University and is looking for the crown disc every day. He has commenced the 6″ doublet for Harvard College Observatory and a 4″ doublet for a private observatory. He hopes to have a little rest in August as the work on Dr. Max Wolf's large photographic objectives should be undertaken as soon as Dr. Schott has finished the discs.

He has completed the optical outfit for the great spectroscope for the Royal Observatory of the Cape of Good Hope and the optical equipment for the new spectroscope for the Lick Observatory is also about finished.

Photographic Objectives.—Some American opticians and physicists have been recently doing hard work in trying to perfect independent photo-

graphic objectives. Astronomers who work in the lines of celestial photography very well know that the astronomical photographic lens, though especially made for that kind of work, is by no means yet as perfect as doubtless it soon will be. This kind of lens is of recent origin and experience in its use is limited. The six-inch photographic lens in use at Goodsell Observatory, by Hastings and Brashear, has done very good work, as has been shown by the number and great variety of photographs procured by it during the last three years. By careful examination of this lens it seems to us safe to say that it is freer from astigmatism than any other similar lens we know. We have had great satisfaction in its use.

Report of W. H. H. Christie, Astronomer Royal, Greenwich Observatory.—The presentation of matters at the Royal Observatory of Greenwich has some points of new and special interest. One is that the re-organization of the Staff at the Observatory has been sanctioned by the authorities. This step has been recommended for two years past. As now constituted, the future Staff will consist of Upper Staff, Lower Staff and Temporary Staff. The first division consists of two chief assistants and five assistants; the second, of two high grade established computers and six established computers, while the Temporary Staff is made up of non-established computers. The Astronomer Royal takes a hopeful view for future astronomical work on account of the re-organization of the Observatory Staff which provides for increased efficiency.

The Greenwich Astrographic Catalogue of Stars—The Astronomer Royal, of England recently reports that, "it is estimated, if no unforeseen difficulties arise, the measures and calculations for the Greenwich Astrographic Catalogue of Stars down to the eleventh magnitude, from declination 64° north to the Pole will be completed in about seven years, and that the positions of about 120,000 stars will be determined with a degree of accuracy at least twice as great as that of the Astronomische Gesellschaft Catalogue from meridian observations. When it is considered that the Greenwich Astrographic Catalogues will contain about ten times as many stars as the catalogues of the Astronomische Gesellschaft for the corresponding zones, and that the Astrographic Catalogue for the whole heavens will give the positions of from two to three million stars with an accuracy hitherto unattained, and at a relatively small expenditure of labor, the great advantage resulting from the application of photography to the mapping of the heavens will be sufficiently apparent."

The basis of this Astrographic Catalogue must be a meridian catalogue having enough stars with accurate positions from which to determine the constants of each photographic plate. The stars of the Greenwich Zone, given above, will be re-observed for this purpose, and it will probably take ten years to do this piece of fundamental work.

Heliometer Triangulation in Coma Berenices.—Frederick L. Chase, of the Observatory at Yale University, has recently completed a handsome piece of useful work in triangulating all the stars which are within about a degree and a half of the center of the cluster, Coma Berenices, which are as bright as magnitude 8.5, according to the Bonn Durchmusterung, this being about the lowest limit at which reliable observations can be made with the Yale heliometer. A fine lithographic chart of the triangulation of this star group is frontispiece to the publication. The plan of the work is somewhat similar to the second method employed by Dr. Elkin in triangulating the Pleiades group. This paper is Part V of Vol. I of the transactions of the Observatory of Yale University.

Messrs. Kandler & Gærtner.—A new firm of instrument makers under the title of Kandler & Gærtner has been recently established in Chicago. These gentlemen have had large experience in designing and constructing instruments for scientific research, and they are ready for work involving such responsibility. We are told that Mr. Kandler was in the employ of Starke & Kamerer in Vienna for many years; and that Mr. Gærtner is a graduate of the Fachschul für Mechaniker in Berlin which is an institution established by the Gesellschaft für Optik und Mechanik, the purpose of it being to train instrument makers. Mr. Gærtner has been connected with the famous A. Repsold & Sons, of Hamburg, the United States Coast and Geodetic Survey, and the Smithsonian Astrophysical Observatory at Washington, and with A. Hilger, of London. By those who are in position to know, it is said that this new firm is worthy of favorable consideration and general patronage.

Astronomical and Physical Society of Toronto.—One of the most recent events of interest in our society is the resumption of work by the lunar and opera glass sections. Much advance is being made among the members in the study of the Moon. Mr. Andrew Elvins has presented the society with a beautiful map of our satellite drawn by Astronomer T. Gwyn Elger, F. R. A. S. Dr. Donaldson, of Fergus, says that a power of 326 diameters or a 3½ inch telescope the three central mountains in Copernicus can be plainly seen, as well as the "straight wall."

Observers interested in solar observations find that the Sun is now remarkably clear of spots. Mr. G. G. Pursey reported at a recent meeting of the Astronomical and Physical Society of Toronto that for several days no spots have been observed. This brought up the question of photographing the solar corona without the aid of an eclipse of the Sun. Some astronomers have published reproductions of photographs alleged to have been taken by a method announced as new, but American astronomers claim that the results reached were due to optical effects when a small pin hole is used for the purpose of admitting the light, as was the case. Mr. Shearmen, of Brantford, corresponding member of the society, has long been engaged in this class of work, and is preparing a paper on the subject, which will be published shortly. Until Mr. Shearmen's views are made known it will be well to suspend judgment as to whether the corona in broad daylight has been captured on the plate.

Dr. J. A. Brashear, of Allegheny, has joined the Astronomical and Physical Society of Toronto as a corresponding member. He has promised to favor the society with occasional accounts of his work.

Members of the Astronomical and Physical Society of Toronto especially interested in physics are not satisfied with the Society's share in X ray experiments and intend to repeat some of Tesla's work in projecting images of the invisible upon a flourescent screen.

JOHN A. COPELAND.

Toronto, Canada.

Professor of Mathematics or Astronomy in College.—A gentleman of high attainments in mathematics and astronomy and a well known author and writer, who has had a long experience both in teaching and in astronomical work, desires a position as professor of mathematics or Astronomy in a college or university of repute. Further information furnished on application to the editor of POPULAR ASTRONOMY. Of the ability of the person referred to above to fill such a position there can be no question.

Dr. T. J. J. See, University of Chicago, has been taking a few weeks of rest at his old home, Montgomery City, Missouri. He has done a prodigious amount of work during the last year, and a vacation was greatly needed. His plans for the coming year will be spoken of later.

S. W. Burnham, spends most of the summer in Chicago. A short trip to New England will be his only summer vacation.

E. E. Barnard, remains in Chicago for nearly all the summer months. He is busy in completing some unfinished astronomical work which needs his personal attention.

Miss Mary Proctor, who has gained not a little reputation in the East, as lecturer on popular astronomical themes, during the last year, is now on a trip to northern Norway to observe the total solar eclipse and the midnight Sun.

Professor S. P. Langley, Secretary of the Smithsonian Institution, Washington, D. C., sailed for Europe, July 8 to be abroad two months.

Lord Kelvin's Jubilee, commemorating fifty years of distinguished service as Professor of Natural Philosophy in the University of Glasgow was duly celebrated June 16, 17 and 18. Many delegates from England, the Continent and some visitors from abroad were present.

Professors S. Newcomb and Cleveland Abbe, of Washington are abroad. They were recently each honored with the degree of LL. D. by the University of Glasgow.

Professor Herman S. Davis, from the Observatory of Columbia College, New York City, July 18, sailed for Europe for a brief vacation season.

Professor Winslow Upton, Director of Ladd Observatory, Brown University, Providence, R. I., has a leave of absence and will spend some time at the Harvard College Observatory station in Arequipa, Peru, South America.

NEW BOOKS.

Solid Geometry.—This brief course in Solid Geometry has been prepared by William C. Bartol, of Bucknell University, Lewisburg, Pa., and is published by Messrs. Leach, Shewell & Sanborn, of Boston, New York and Chicago.

The author's aim has been to condense the work of solid Geometry, somewhat, as studied in the ordinary college curriculum that the student thereby may have more time for advanced mathematics.

The selection of matter is good, and the feature of the mensuration of solids a useful one in the pursuit of the advanced mathematics. The cuts are not up to the grade of the rest of the book. The fault evidently lies with the engraver. In these days of cheap fine engraving it is a surprise that such work should be admitted to a text-book. Geometrical figures should be models of neatness and skill, that students who copy them may gain instinctly the ideas of taste and finished work while presenting rigid courses of reasoning. The Elementary Geometry is a most useful branch of study for culture in this direction.

Trigonometry for Schools and Colleges, by Frederick Anderegg and Edward Drake Roe, Jr., Professors in Oberlin College, Ohio.

This small text-book of 108 pages in Trigonometry presents several things that deserve attention. The definitions are somewhat broader than is usual in text-books in this branch, the figures and equations from the first present a negative concept for angles and lines as well as a positive one, angular units are given in both the ordinary sexigesemal way and also in the centesimal system. A right angle in the latter system consists of 100 grades, and 1 grade of 100 minutes (100′) and 1′ of 100 seconds (100″). The convention about angles positive and negative, and the triangle of reference by the use of an X-axis and a Y-axis of reference are the same as ordinarily used in analytic geometry. The principles are simple enough to be introduced at this stage of mathematical study without confusion, and it is well enough to do so if the ratio idea of hypotenuse and side of a triangle is deemed the best way of defining trigonometric functions. We prefer the purely geometrical method in defining these functions.

Is it desirable to burden the student's mind at this stage with the suversed-sine and sucoversed-sine? The functions to be used generally seem to us to be enough.

The theoretical part of this book is well presented, but it seems to us that the practical part is too limited. There ought to be trigonometric and logarithmic tables in connection with every elementary text-book in trigonometry. In our experience it is not best that a student's mind be so fully occupied with the theory of the subject that he has not time enough to fix the meaning of principle and method by necessary work to the extent of considerable invention, in the direction of examples and problems. In these particulars the authors need not fear that they will trench on the liberty of the instructor by a well graded system of exercise to carry out even their own plan of theoretical development.

This book is published by Messrs. Ginn & Co , of Boston and Chicago.

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All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.